

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

Public Reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comment regarding this burden estimates or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188,) Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE 31 December 2001		3. REPORT TYPE AND DATES COVERED Final - STIR (1 June 2001 - 30 November 2001)	
4. TITLE AND SUBTITLE Ecological Soil Characterization of the Delta Creek and Washington Impact Areas, Fort Greely, Alaska				5. FUNDING NUMBERS Research Agreement No. DAAD19-01-1-0608	
6. AUTHOR(S) Dr. Robert B. Shaw, Dr. William W. Doe III and MAJ (P) Steve Houston					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for Environmental Management of Military Lands Colorado State University Fort Collins, CO 80523-1490				8. PERFORMING ORGANIZATION REPORT NUMBER N/A	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211				10. SPONSORING / MONITORING AGENCY REPORT NUMBER P-42701-EV-II 42701.1-EV-II	
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.					
12 a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.				12 b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Munitions use on military lands is of keen environmental interest primarily due to the potential for contamination from unexploded ordnance (UXO) constituents. Explosive fillers such as Trinitrotoluene (TNT), Royal Demolition Explosive (RDX), and High Melting Explosive (HMX) are subject to environmental fate and transport congruent with the ecological setting into which they are released. Key environmental processes are dissolution, adsorption and chelation processes and biological action. The expected soil component responses might be recovery from cratering through organic matter inputs, and the assimilation and transformation of explosive compound contamination within the soil matrix. The spatial and temporal characteristics of munitions disturbance and important ecotype soil quality attributes were examined for an Army range impact area at Ft Greely, AK. Forty-eight control plots, twelve impact area plots, and five craters were examined. Cation exchange capacity (CEC) was highly correlated to soil organic matter (SOM) and there appears to be a significant gradient of soil quality characteristics for craters. Characterizing the distribution and dynamics of SOM may improve ecosystem management in the face of evolving contaminant threats. Once SOM for a particular system is characterized it can then be readily modeled and used as a resiliency metric for use in management decision models.					
14. SUBJECT TERMS Army Range Impact Areas; Unexploded Ordnance; Munitions Disturbance; Ecological Response ; Soil Quality				15. NUMBER OF PAGES 86	
				16. PRICE CODE N/A	
17. SECURITY CLASSIFICATION OR REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION ON THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL		

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. Z39-18
298-102

20020125 257

Introduction

Munitions use on military lands is of keen environmental interest primarily due to the potential for contamination from unexploded ordnance (UXO) constituents. There has been little research on ecosystem response to munitions use. Demarais, et al., (1999) describe a wide array of spatial and temporal disturbance regimes and agents of disturbance associated with military training. They summarized the limited body of knowledge related to the live-fire training and its physical, chemical and biological effects on the environment. However, little is known of the ability or capacity of an impact area ecosystem to respond to munitions disturbance. Munitions use in the Washington Impact area at Fort Greely, Alaska provides an opportunity to examine the effects of munitions use in an ecosystem as well as the ecosystem's response.

The objectives of this study are to:

- Examine the spatial and temporal characteristics of munitions disturbance.
- Describe and relate important soil quality response/capacity attributes that directly influence the ability of the ecosystem to influence the fate and transport of potential UXO contamination.
- Resolve these attributes into a measurable metric or indicator that can then be used to evaluate ecosystem response.

Background: Impact Area Design, Disturbance Regime and Ecosystem Response

Impact Area Design

Impact areas are the ground and associated airspace within a training complex used to contain fired, dropped or launched munitions and any resulting fragments, debris, and components (CEMML, 1999). The Army's Readiness Program requires that impact areas provide effective individual, crew, and unit live fire and maneuver proficiency training using the Army's current and projected modern weapons systems (AR 210-21, 1997, p.10). Therefore, impact areas reflect a mission-oriented design that is continually being updated to accommodate technological and doctrinal changes.

Impact area lands are more effectively utilized by grouping firing ranges so that safety danger zones (SDZ, i.e., the hazardous, three dimensional space along a line from the gun to the target to include areas around the gun and target) associated with individual weapons systems overlap. This not only reduces the area required for live fire training, but also minimizes the area contaminated by UXO. Additionally, impact areas are segregated from surrounding maneuver areas and from public and private lands to avoid unintentional contact with UXO, which can be physically hazards. They

are intended for indefinite use (AR 210-21, 1997, p.15) because of the challenges and uncertainties associated with clearing UXO. As such, they represent a potential source of environmental contamination either from UXO residues or from other sources such as sediment pollution caused by normal cratering effects. Therefore, current impact area design and management of older impact areas, incorporates a high degree of environmental planning that includes pollution prevention, and natural and cultural resource protection considerations (TC 25-1, 1991, p.3-4)

Impact area size primarily depends upon the size and type of units designated to use them. An U.S. Army installation usually accommodates approximately one Army division. Divisions typically consist of 10,000 to 15,000 soldiers and their equipment and they have different missions and organization such as light infantry, air borne, air assault, mechanized infantry and armor. For example, armored divisions are equipped with hundreds of armored combat systems such as tanks and infantry fighting vehicles, while light infantry divisions have no armored combat vehicle systems.

Combat readiness is a measure of a unit's ability to accomplish its assigned wartime mission. Many of the readiness capabilities assessed involve how well individual soldiers and combat crews employ their individual and crew served weapons systems. Therefore, Army range objectives are tailored to provide ranges and associated impact areas to ensure combat readiness of the division assigned to the installation (Table 1). Ranges are generally designed for direct fire or indirect fire weapons systems or for a combination of system types. Based on these range requirements, one can determine an approximate target and target array area requirements within an impact area for a given set of ranges. Direct fire weapons systems such as tanks and anti tank systems are those that fire to a point target such as an enemy tank or fighting position. They require a series of single targets each of which occupy a relatively small area on the order of a quarter hectare. Indirect fire weapons systems are those employed against area targets such as a group of enemy vehicles or soldiers. They require groupings of targets or target arrays that occupy a somewhat larger area on the order of one hectare. Typically, division sized range facilities and impact areas require on the order of one or two thousand targets and target arrays occupying many hundreds of hectares within impact areas.

The impact area that is the subject of this study is at Fort Greely located in Alaska. Fort Greely has been an active Army installation for over fifty years. The installation covers around 267,905 hectares and has 34,415 hectares of high hazard impact areas – those in which high explosive munitions are employed (Figure 1 and Landsat image at Appendix A). Its impact areas were designed to support a division-sized unit, although today only one brigade (approximately 25% of a standard division) trains at Fort Greely.

Anthropogenic Disturbance

Munitions use and fire resulting from both munitions use and maneuver training are significant disturbance gradients operating at Fort Greely. An examination of the types of munitions used in an impact area, the quantities expended, and an approximation of the magnitude of potential contaminant loading provides a measure of the problem under consideration. High explosive munitions are the focus of this study because they have both a destructive and contaminate effect in the environment. High explosive munitions are those that explode on or near the ground and therefore have the potential of creating a crater. Other munitions include smoke projectiles, illumination projectiles, and small arms and inert projectiles (CEMML, 1999). These munitions have the potential of creating craters, but this potential is relatively small compared to high explosive munitions.

The magnitude of the physical disturbance occurring within Fort Greely impact areas can be approximated by an evaluation of munition expenditure data for the period 1992-1997 (Table 2 and Tabular Data for Munitions Loading at Appendix B). Fort Greely's high hazard impact areas had at least 185,846 high explosive munitions fired, launched or dropped into its impact areas or approximately 30,974 munitions per year (CEMML, 1999). To account for the area exposed to high explosive munitions, one can approximate the surface area of target arrays. This area could encompass up to 945 ha exposed to munitions disturbance, or about 2.75% of the total impact area lands. Determining the approximate annual cratered surface area refines this estimate of disturbance. Again, using the CEMML (1999) data set and assuming a crater radius for each type of munition it can be determined that approximately 10.21 ha were disturbed annually during this period representing approximately 1.08% of the lands exposed to munitions or less than 0.03% of the total high hazard impact areas.

In addition to the inherent kinetic and blast destructive effects of munitions, there is a little understood contaminant effect associated with munitions that fail to function properly. There are two modes of munition failure – dud and low order detonation. A dud is a round that completely fails to function at the target while a low order detonation is a round that only partially functions leaving part of the high explosive filler scattered over the target area (USATCES, 2000). Dud rounds retain their explosive filler inside the delivery body of the munition and are relatively isolated from the environment. However, during impact the delivery body can become fractured and over time there is the possibility that small amounts of explosive filler can be mobilized through dissolution with water. Low order detonations can result in significant amounts of ready availability explosive filler for dissolution and subsequent movement into the environment (Brannon et al., 1999). Therefore, both dud and low order detonation munitions have the potential for environmental contamination by leached explosive filler.

Explosive fillers such as Trinitrotoluene (TNT), Royal Demolition Explosive (RDX), and High Melting Explosive (HMX) are subject to environmental fate and transport congruent with the ecological setting in to which they are released. Release is contingent on dissolution rates and there have been a limited but varied number of

reported rates. Brannon et al. (1999) reported the dissolution fluxes for free solid to liquid phase. Their model considers dissolution flux critical for quantifying contaminant-loading rates. They report TNT has the highest rate at $4,164 \mu\text{g cm}^{-2} \text{hr}^{-1}$; HMX has a rate of $454 \mu\text{g cm}^{-2} \text{hr}^{-1}$, and RDX's has the lowest dissolution rate at $360 \mu\text{g cm}^{-2} \text{hr}^{-1}$. Lynch et. al, (2001) report much higher rates of $604,800 \mu\text{g cm}^{-2} \text{hr}^{-1}$, $25,056 \mu\text{g cm}^{-2} \text{hr}^{-1}$, and $8294 \mu\text{g cm}^{-2} \text{hr}^{-1}$ for TNT, HMX and RDX respectively. They used weapons grade explosives and subjected samples to mixing, which may be more similar to particular environmental conditions such as free product exposed to surface water flow. Since dissolution is a function of interfacial surface area, temperature, and energy input (i.e. degree of fluid motion), they may have observed these higher rates due to relatively large energy input. Also, dissolution rates of pure explosive will differ from the rate of mixtures of explosives used in munitions (e.g., an artillery munition may have a mixture of TNT and RDX). This is because most manufacturing processes result in one explosive encapsulated within another explosive, or within compounds that serve as explosive binders. For example, "certain formulations include binders made of insoluble wax; explosives almost entirely encapsulated in wax would persist for extended periods of time yet yield comparably lower concentrations." (Lynch, 2001, personal communication).

The magnitude of the contaminant threat can be approximated by an evaluation of munition failure rates. Using failure rates published by USATCES (2000) and assuming the same failure rates are applicable to Air Force munitions, analysis indicates that there could be approximately 1,271 dud and 95 low order munitions failures per year on Fort Greely impact areas. Loading rates could be derived from this data, but the highly variable nature of the state of explosive fillers available for mobilization (e.g., fully contained in a dud delivery body, partially contained in a low order delivery body and/or scattered by a low order detonation) coupled with varying solubility and dissolution fluxes resulting from manufacturing processes makes any attempt very uncertain. The most conservative approach to assume that all of the explosive filler from dud and low order munitions failures is available for dissolution. Assuming, optimum dissolution conditions this results in a maximum potential annual average of 4,460 kg of high explosive materials and translates into a maximum theoretical loading rate within the target array area exposed to high explosive munitions of about $0.46 \text{ gm m}^{-2} \text{yr}^{-1}$. Alternatively, assuming that this maximum potential annual average of high explosive materials is deposited in cratered areas, the maximum theoretical loading rate could be as high as $44 \text{ gm m}^{-2} \text{yr}^{-1}$ (Table 2). Assuming this load resides in the top 1 cm of the soil profile, a soil bulk density of 2.0 Mg m^{-3} (e.g., glacial till; Brady and Weil, 1999, p. 136), and that no transformations take place, this equates to potential concentrations ranging from $0.046 \mu\text{g gm}^{-1}$ for target areas to $4.4 \mu\text{g gm}^{-1}$ for craters for a given year. This is potentially well below Environmental Protection Agency residential risk based concentrations (i.e., 5.8 to $3900 \mu\text{g gm}^{-1}$ for various explosives) reported by Walsh et al., (2001).

Finally, the other major form of human disturbance is in the form of fires started either by maneuver training or by munitions use. Jorgenson et al. (2001) report that fire frequencies and percent area burned are slightly higher than similar forest types in

interior Alaska. Since 1950, 1.2% of Fort Greely has burned annually whereas interior Alaska forestland has exhibited percent annual burn areas ranging from 1% between 1940 and 1970, to 6 % between 1970 and the present. This slightly higher percentage is consistent with the effects of military training (Demarais et al., 1999). Fire is significant in this landscape because it is the dominant process affecting succession (Jorgenson et al., 2001) and is ultimately important in any soil forming process.

Soil, Climate and Hydrologic Ecosystem Component Response

When considering ecosystem response in the face of disturbance one naturally thinks of the manner in which a disturbed system recovers. A measure of stability is the concept of resilience or the time it takes a system to return to a steady state following perturbation (DeAngelis et al., 1989). Climate, soils, hydrology, flora and fauna interact and affect energy, moisture, nutrient and disturbance gradients which in turn regulate the structure and function of ecosystems and their ability to rebound from disturbances (Jorgenson et al, 2001). High system resilience has been characterized in terms of high energy fluxes through food webs and short nutrient cycling times (O'Neill, 1976; DeAngelis, 1980, 1989; Harwell et al., 1977; and Loreau, 1994). In the case of impact areas, expected soil component responses might be recovery from cratering through organic matter inputs, and the assimilation and transformation of explosive compound contamination within the soil matrix. These responses should be intimately tied to biomass inputs, and to processes that influence nutrient availability within the soil component.

Fate and transport processes are continuously at work within the environment. Brannon et al. (1999) developed a conceptual model for fate and transport of UXO that provides a basis for a qualitative evaluation of the key processes at work in the environment. Their model outlined representations for soil, sediment, and water environments, described source term considerations, and developed descriptor formulations of key processes resulting in explosive contaminant mobilization, retardation, and transformation effects. With modifications, these key processes are dissolution, the initiating release mechanism described above; adsorption and chelation processes in soils, considered to be an important retardation mechanism; and biotic transformation, or for the purposes of this study biological action, consisting of metabolism by microorganisms and uptake by plants. Biological action is regarded as an important transformation mechanism (Comfort et al., 1995; Larson et al., 1998a; Pennington, 1988; Price et al., 1998; Brannon et al 1999; Pennington et al., 1999a; and Pennington et al., 1999b).

Applying this conceptual model into an Alaskan ecological framework involves relating process and effect to relevant ecosystem components and their governing ecological setting. For example, dissolution is the process by which TNT, RDX and HMX are dissolved by a solvent from free product to solutes. In this case, the solvent is water that is provided via the hydrologic cycle. The hydrologic cycle is an ecological component that determines the availability of water, and its relative importance is

governed by the ecological setting of the region in which UXO is located. In Fort Greely, water is available in an unfrozen form for relatively short time frames.

Adsorption is the process by which solutes move to and bind with a sorbent. This process is reversible and is dependent on the partitioning affinity of the solute for either the solute or sorbent (LaGrega et al., 1994). For this analysis, the process is the movement or partitioning of dissolved TNT, RDX, and HMX to soil colloidal surfaces. Generally, soil colloidal surfaces, composed of clays and humic matter, are negatively charged. In the subsurface, adsorption is primarily a process of positively charged organic chemicals accumulating at these colloidal soil surfaces of which naturally occurring humic matter in soil plays a significant role (LaGrega et al., 1994). Therefore, the notable parameter for adsorption is colloidal content of the soil component. Colloid content can be measured via a soil's cation exchange capacity (CEC) which in turn is used to define a partitioning coefficient for contaminant to soil adsorption. In terms of the influence of ecological setting on the adsorption process, one can evaluate the soil quality and its CEC to obtain an indication of the relative retardation potential of the area in which UXO is found. Generally, Alaskan soils are not as weathered as soils in more temperate regions. Therefore they generally have less clay fraction and humus becomes the dominant contributor to CEC.

Adsorption of TNT to soil has been documented and considered to be very important in immobilizing TNT and its transformation products (Larson et al., 1998b; Pennington et al., 1999c; Comfort et al., 1995; Weissmahr et al., 1998; Myers et al., 1998) and in particular to humic soils (Hundal et al., 1997). TNT adsorption has been positively correlated with cation exchange capacity (CEC) of soils (Pennington, 1988; Brannon et al., 1999). RDX has been shown to sorb at lower rates than TNT (Singh et al., 1998; Price et al., 1998) and also can be positively correlated with soil CEC characteristics (Brannon et al., 1999). While HMX adsorption occurs, little is known about the solute-sorbent process to enable the prediction of adsorption coefficients for HMX (Brannon et al., 1999).

Metals availability are largely determined by the colloidal portion of soil organic matter (Tate, 1987). Humic acids contain highly reactive anionic groups that chelate or complex metals. Tate (1987) states that due to the high reactivity of these groups there is a positive relationship between degree of humification and complexation. This relationship should be less pronounced in acidic soils as may be the case in Alaska where coniferous forests intensify soil acidity.

Biological action consists of the mechanisms of biodegradation and bio-uptake of contaminants. Biodegradation involves the oxidation and reduction of organic contaminants and bio-uptake of organic and inorganic contaminants involves plant root uptake by vegetation. Both depend on the ecological components of soil and climate. Soil structure provides habitat for microorganisms, which obtain energy and carbon from the soil. Vegetation requires soil for structural support, for a source of oxygen for root respiration, and for a source of macro and micronutrients. Soil microorganisms and plants both require water and a temperature regime conducive for growth, which is a

function of climate. Soil organic carbon (SOC) content and climate in terms of effective growing season (EGS) are good indicators of conditions favorable for microbial and plant activity. SOC and EGS can provide a relative measure of the transformation potential of the region in which UXO is found. In Alaska, growing seasons are relatively short so biological activity may not be as great as in more temperate regions.

Biologically, TNT can undergo both aerobic and anaerobic degradation (Brannon et al 1999; Larson et al., 1998a; Pennington et al., 1999a) provided there are sufficient carbon and energy sources for microorganisms (Pennington et al., 1999b). RDX and HMX undergo biodegradation only under anaerobic conditions (Price et al., 1998; Comfort et al., 1995 as reported by Larson et al., 1998a). Vegetation also can act as a sink for explosive contaminants by root uptake (Larson et al., 1998a).

All of the explosives, as with any solute, can be transported by groundwater advection. These UXO fate and transport characterizations help to serve as the conceptual foundation for the development of a framework for the ecological assessment of impact area resilience.

Spatial and Temporal Scaling of Ecological Soil Evaluation

An ecological soil evaluation is an examination of soil quality and of ecosystem response to disturbance. Therefore, this research effort is designed based on appropriate scaling of the soil component processes and of disturbance response. Also, as one begins to evaluate the ability or capacity of an impact area ecosystem to respond to munitions disturbance one must be concerned with the relevant spatial and temporal scales associated with impact area use. Therefore, the first step in this evaluation process is one that determines the appropriate spatial and temporal scales of interest relative to munitions disturbance and UXO contamination.

O'Neill et al. (1986) argue that a critical step in addressing any problem is determining the scale of observation. This allows one to focus on a particular organizational level characterized by a range of rates that can be segregated from higher and lower levels of dynamics thereby describing a system that is conducive to study the results of which are not confounded by indifferent dynamics. This approach is further supported by Wiens (1989) who states that the goal of an investigation should be to obtain a balance between extent and grain (i.e., the upper and lower limits of resolution respectively) in order to minimize the spatial variance of a process of interest. Ecological setting, munitions use effects, soil quality indicators and information management requirements are scalar-sieves that can be used to define appropriate scales of interest and relevant parameters. Ecological setting provides a general indication for appropriate upper level scaling rational. An examination of munitions use within an impact area helps to define the anthropogenic disturbance regime resulting in a higher degree of spatial and temporal resolution. Soil quality indicators help to describe relevant large-scale (i.e., local) processes and provide a refined indication for both spatial and temporal scaling in terms of ecosystem response. Finally, information

management requirements integrate all of these scalars into an investigative arrangement.

Ecological Settings

The ecological settings, or the dominant ecosystem components of interest, are important in helping to determine spatial and temporal scales of interest. As described above, climate, soils, hydrology, flora and fauna are examples of ecosystem components. They interact and they affect energy, moisture, nutrient and disturbance gradients which in turn regulate the structure and function of ecosystems (Jorgenson et al, 2000) found within the boundaries of an impact area. They involve complex processes that demand a hierarchical approach designed to define the system of interest and the types of measurements and their interpretations taken on the system (O'Neill et al., 1986). This allows one to determine and focus on a component of interest and its range of variation. Components that have slower rates become background and components with faster rates are averaged out (O'Neill et al., 1986). Relevant components in this evaluation are climate, flora and soils.

The climate of the system determines the availability of liquid water, which will largely determine the potential for, contaminate mobilization (Brannon et al., 1999). Also, it is a major determinant in vegetative growth and soils development. However, it operates at spatial temporal scales that are at higher levels and at slower rates of change than the disturbance response phenomena of interest. Climate is therefore considered a background component.

Since the majority of the contaminant threat lies at or near the surface of the ground, the soil component is an important ecological setting for an impact area at Fort Greely. The flora component and the successional characteristics of the system are intimately tied to soil development and therefore soil component processes should be reflected at the forest stand level. If one considers the extent of the study to be the boundaries of the impact area and the major forest ecotypes that populate it, then the grain should be at a scale that minimizes spatial variance within these boundaries. With extent held as a constant scale would be held constant the grain would be scaled at the level of sub forest stand. This should be large enough to decrease between grain spatial variance within the extent of the study area.

Munitions Use in Impact areas – Levels of Disturbance

Walker and Walker (1991), describe a hierarchy of disturbance scales in Arctic Alaska. They state that anthropogenic disturbances are generally on the microscale level (10^{-1} to 10^6 m²), and that cumulative impacts are on the mesoscale level (10^6 to 10^{10} m²). This is particularly true of munitions use in impact areas wherein munitions cause craters that range in size from less than a meter to several meters in diameter. Also, impact areas accommodate firing of weapon systems that have ranges on the order of tens of kilometers and must retain the effects munitions requiring several

hundred to thousands of hectares. Temporally, munitions use within impact areas falls within the natural disturbance frequency range between 1 and 1000 years (e.g., monthly use over a period of fifty years), and is within the same recovery timeframe. Therefore, an evaluation that is intended to examine munitions use over spatial and temporal scales of hectares to square kilometers and years to hundreds of years respectively, falls comfortably into a microscale to mesoscale spatial and temporal realm as defined by Walker and Walker (1991). Finally, these scales of observation lend themselves to data derived from satellite sensed data and surface surveys to examine anthropogenic effects such as cratering and ecosystem recovery.

Inherent Soil Quality Indicators

Soil quality should be affected by munitions use primarily through physical disturbance. Contaminant fate and transport in soils is dependent on same soil chemical properties that influence nutrient availability and uptake by plants and microorganisms (Heil and Sposito, 1997). Therefore, an examination of significant physical, chemical and biological indicators and their associated processes will provide an indication of appropriate spatial and temporal scales of study.

Topp et al., 1997 describe several physical attributes of soil quality. Key among them is soil water transmission and soil strength. Soil water transmission capability determines the rate at which excess soil water drains out of the root zone and reflects system water availability and matter transfer potentials. It is described by the soil's saturate hydraulic conductivity with rates ranging from 10^1 to 10^3 meters/year for fine to coarse textured soils respectively (Topp et al., 1997). Soil strength is a function of cohesion and friction and is a soil's ability to resist shear breakage, which is potentially important in physical disturbance response. It can be assessed over short spatial and temporal scales of square meters and years. Both soil water transmission and strength can be related to soil texture (Topp et al., 1997).

Chemical attributes of importance include mineralogy, pH, buffer capacity, organic matter, and cation exchange capacity. They affect rates of reaction for processes such as soluble complex formation, adsorption, mineral dissolution, are relevant to plant growth, (i.e. available nutrient utilization, mobility of nutrient species, and diffusion processes) and are on the order of meters/year (Heil and Sposito, 1997). A notable biological input into the chemical system is humus in organic matter provides reactive colloidal adsorption sites for nutrient storage and in doing so affects cation exchange capacity (Heil and Sposito, 1997). Organic matter has transformation and colloidal production rates that range from a few years to centuries (Parton, 1996).

Gregorich et al. (1997) describe two primary biological indicators of soil quality. They are total organic carbon and nitrogen and are related to soil organic matter dynamics resulting from management practices such as tillage. Cratering effects of munitions can be related to tillage. Long term studies are required to observe

significant changes soil organic matter accumulation or loss. Associated spatial and temporal scales are on the order of hectares and tens to hundreds of years.

Overall, spatial and temporal scales of interest are bounded by physical, chemical and biological properties of the soil component. Chemical properties seem to be generally aligned with small spatial and temporal time scales relevant to plant growth. Physical properties are generally aligned with slightly larger scales. Biological indicators are somewhat larger than chemical and physical indicators, and on the order of hectares and tens to hundreds of years. Also, biological indicators are significant in that they represent a higher level of system dynamics controlling chemical and physical soil properties. Based on the discussion above, key indices for soil quality as they relate to munitions use may be:

- pH and Buffer Capacity
- Cation Exchange Capacity
- Nutrient Status (e.g., N, P, K)
- % Sand, Silt, Clay (Texture)
- % Organic Carbon and Organic Matter

Information Management

Information management allows one to understand technological limitations and capabilities and at the same time helps to integrate relevant spatial and temporal scales into a system which is not confounded by higher and lower levels of dynamics. In effect, it allows us to determine sampling methodology and subsequent analysis. Sample plot size is a compromise between the area utilized by a typical target array, the spatial resolution of sensor and mapping software, and an area that is conducive to effective land management. A one-hectare plot size meets all of these conditions. Target arrays range in size from 100 m² for direct fire targets to 1-4 ha for indirect fire targets; one hectare equates to 12.3 pixels of Landsat TM data (28.5 m spatial resolution); filtered (i.e., a 3x3 or a 5x5 majority filter) thematic classifications of TM data resolve to approximately 0.7-2 ha; and one hectare is a universally used management unit. (Figure 2). Temporally, remotely sensed data can provide recent and timely information about disturbance and response. Finally, soil quality information can be easily obtained and readily assessed at these scales.

Ecological settings provide a macro scale perspective, which is critical to understanding higher lever background dynamics. Munitions use helps to further define the extent of the problem narrowing the range of spatial and temporal scales. Soil quality is dominated by process dynamics that operate at scales relevant to the grain of measure and represents a micro perspective. Information management allows one to realize a balance between higher and lower level of dynamics within technological capability.

Methods

Study and Control Area Descriptions

Fort Greely Military Installation is located in central Alaska approximately 160 km to the southeast of Fairbanks, near the city of Delta Junction. The installation covers approximately 267,900 ha and consists of the cantonment area, West Training Area and East Training Area. Fort Greely is a US Army training and testing installation with approximately 34,400 ha of high hazard impact areas. The Washington impact area is the subject of this study and is used for a variety of weapons testing and training involving mortar and artillery firing exercises, tank gunnery, and aerial bombing. Washington impact area is set in a riverine floodplain and encompasses approximately 800 ha within the Delta River floodplain (Walsh, et al., 2001). At the south boundary of the impact area is a portion of the Washington Range (i.e., an area from which weapons systems are fired into the impact area). This area extends approximately 2.5 kms to the south, is very similar to the impact area and is a control area for the study. It is called the Washington Range control area (Figure 1).

The second control area Jarvis Creek control area is approximately 15 km to the east-north-east of the Washington impact area is used for maneuver training and is named for Jarvis Creek that runs along the training area's western boundary. The area is similar to Delta River in terms of direction of water flow, elevation, geomorphic units and ecotypes (Jorgenson et al., 2001).

Further description of control areas and study area can be made in terms of the dominant ecosystem components of the Fort Greely area, which are climate, physiography, hydrology and disturbance. The climate of Fort Greely as described by Bailey (1998) is Boreal Subarctic characterized by a great seasonal range in temperatures. While its climate is moist all year, Fort Greely has relatively small annual amounts of precipitation that is concentrated in warm months. Winter is the dominant season with cool short summers. Weather data covering 63 years from Big Delta FAA/AMOS AP, AK (500770) indicates that January is the coldest month with an average maximum temperature of -16.1C and average minimum temperature of -24.1C. July is the warmest month with an average maximum temperature of 20.8C and average minimum temperature 10.3C. Total average annual precipitation is 29.5cm with July having the highest monthly average of 6.7cm. Total average annual snowfall amounts to 111.3 cm with October having highest monthly average snowfall of 23.4cm. Average snow depth during winter is 10.2 cm with the month of February having the highest monthly average depth of 25.4 cm. Using the USACERL methodology (Diersing et al., 1990), Fort Greely's effective growing season is 25 May – 31 August (Figure 3).

The region's physiography is described as the Tanana-Kuskokwim Lowlands (CEMML, 1999). It consists of a broad depression north of the Alaska Range on top of coalescing outwash fans that spread northward. The area is generally underlain by

permafrost, however areas over deep gravels and/or on south facing slopes are relatively free of permafrost. Alluvium consists of porous gravel sands. The dominant geomorphic feature associated with the impact area and control areas is glaciofluvial sediment deposits from the past Delta Glaciation and from modern glaciers (CEMML, 1999). Flooding events are generally infrequent, as these areas are located primarily on inactive glacial-fluvial outwash deposits or in inactive floodplains of meandering and headwater streams. Soils are poorly developed Inceptisols, underdeveloped Entisols and Histosols. Both stream systems physiographies are classified as riverine and flat (Jorgenson et al., 2001).

The hydrology of both areas is similar and characterized by braided glacial streams over glacial outwash fans. Both the Delta River and Jarvis Creek flow generally northward from Alaska Range to Tanana River. Delta River, which runs through Washington Impact Area and Fort Greely, drains 4305 square kilometers and is 130 kilometers long. Its primary source is glacial melt water from the Alaska Range and is entrenched up to 60 meters into an alluvial fan. The Jarvis Creek, which runs through control area and Fort Greely, drains 96 square kilometers, is 65 kilometers long and is entrenched into same alluvial fan. It is an influent stream that is dry during the winter, and has high water during spring melt and summer rains (CEMML, 1999). Delta River and Jarvis Creek are perched above single aquifer with varying local confinement. They both streams lose some flow to the aquifer in winter. The groundwater table is less than 10 meters below Delta River and flows to the northeast (CEMML, 1999). Finally, the natural disturbance component for both areas consist primarily of fluvial and fire processes and wind erosion (Jorgenson et al., 2001).

Ecotype Descriptions

Jorgenson et al., (2001) is the primary source for ecological description of Fort Greely. They utilized a hierarchical classification scheme to present three levels of ecosystem organization and descriptions for the Fort Greely installation, which are:

- Ecodistrict – (1:500,000 scale) Middle Tanana Floodplain Common Regional Ecosystem with the Delta River Floodplain, Jarvis Creek Floodplain sub districts.
- Ecosection – (1:100,000 scale) Glacial Fluvial Outwash - Active-riverbed Deposit, Inactive-riverbed Deposit, Abandoned Riverbed, and Inactive Cover Deposit.
- Ecotype– (1:25,000 – 50,000 scale) areas within Fort Greely with homogeneous topography, terrain, soil, surface form, hydrology and vegetation.

Their ecotype descriptions are based primarily on physiography and vegetation structures with the vegetation type or successional stage the differentiating characteristics. They argue that this approach is effective at differentiating soil characteristics and vegetation composition and that the integration of these characteristics is useful in discriminating ecotypes that “may have different sensitivities to disturbance.” (Jorgenson et al., 2001, p.18) which is of particular interest for this evaluation.

The physiography for both areas described above are classified as riverine. There are five riverine ecotypes associated with the study and control areas. These are differentiated by their vegetative cover and consist of scrub, broadleaf forest, mixed forest and needleleaf forest ecotypes and are described below.

The scrub ecotype is what Jorgenson et al., (2001) describe as Riverine Dwarf, Low and Tall Scrub. Vegetation consists of a range of early successional scrub species that are highly variable and frequently includes: *Dryas drummondii*, *Populus balsamifera* saplings, *Shepherdia canadensis*, *Fragaria virginiana*, *Oxytopis campestris*, *Elaeagnus commutata*, *Potentilla multifida*, *Salix alaxensis*, *Potentilla fruticosa*, *Alnus tenuifolia*, *Salix planifolia*, *Betula nana*, and *Calamagrostis canadensis*. Soil profiles range from stratified to massive gravel with occasional thin and sandy layers that lack organics to interbedded silts and sands with thin surface organic layers. These soils are generally well drained (i.e., moist) to excessively drained (i.e., dry) and exhibit activities that range from slightly alkaline to slightly acidic.

The broadleaf forest ecotype is what Jorgenson et al., (2001) describe as Riverine Broadleaf Forest. Vegetation consists of a range of early to mid successional broadleaf species. Open to closed canopies are composed of *Populus balsamifera* (occasionally mixed with *Populus tremuloides*), and *Picea glauca*. Understories consists of *Shepherdia canadensis*, *Potentilla fruticosa*, *Dryas drummondii*, *Fragaria virginiana*, *Ceratodon purpureus*, *Astragalus* spp., *Geocaulon lividum* and *Linnaea borealis*. Soil profiles range from interbedded gravel, sand and silt, lacking in organics to interbedded silts and sands with thin surface organic layers. These soils are generally well drained (i.e., moist) to excessively drained (i.e., dry) and exhibit activities that range from neutral to slightly acidic.

The mixed forest ecotype is what Jorgenson et al., (2001) describe as Riverine Moist Mixed Forest. Vegetation consists of a range of intermediate successional broadleaf and needleleaf species. Closed canopies are composed of *Populus balsamifera*, *Picea glauca*, and/or *Betula papyrifera*. Understories consist of *Shepherdia canadensis*, *Dryas drummondii*, *Fragaria virginiana*, *Ceratodon purpureus*, *Alnus tenuifolia*, *Rosa acicularis*, *Geocaulon lividum*, *Linnaea borealis* and *Hylocomium splendens*. Mixed ecotype soils are similar to those of the broadleaf ecotype described above.

The needleleaf forest ecotype is what Jorgenson et al., (2001) describe as Riverine Gravelly Needleleaf Forest and Moist Needleleaf Forest. Vegetation consists of a range of late successional needleleaf species. Open to closed canopies is composed of *Picea glauca*. Understories consist of *Shepherdia canadensis*, *Solidago canadensis*, *Geocaulon lividum* and *Hylocomium splendens*, *Rosa acicularis*, *Ledum groenlandicum* and *Calamagrostis canadensis*. Soil profiles exhibit interbedded gravel, sand and silt layers, with thin surface organics. These soils are generally well drained (i.e., moist) to excessively drained (i.e., dry) and exhibit activities that are slightly acidic.

Research Hypothesis and Tests

The primary objective of this study is to describe and relate important soil quality response/capacity attributes that directly influence the ability of the ecosystem to influence the fate and transport of potential UXO contamination. Given this objective, this study evaluates ecotype soil properties in undisturbed and disturbed setting. Stated in terms of hypotheses, they are:

1. **H₀:** There is no relationship between ecotype and soil quality.
H_A: There is a relationship between ecotype and soil quality.
Test: Soil samples among ecotypes and t-Tests on paired means of selected indices.
2. **H₀:** There is no relationship between munitions use on a target and soil quality in proximity to the target.
H_A: There is a relationship between munitions use on a target and soil quality in proximity to the target.
Test: Soil samples around target in concentric rings and t-Tests on paired means of selected indices.

Study Design and Execution

This design and execution of this evaluation consisted of three phases:

1. Identification of study plots in the Jarvis Creek control area using a land cover classification.
2. Soil sample collection in the Jarvis Creek control area, the Washington Range control area and the Washington impact study area.
3. Soil sample processing, laboratory and statistical analysis.

Phase 1: Land Cover Classification

Initial efforts centered on creating a thematic land cover classification of the control and study sites producing thematic maps of the Tanana watershed in the vicinity of Fort Greely, Delta Creek impact area, Washington Range impact area and the Jarvis Creek control area. The objective was to generate a land cover classification to achieve the highest level of accuracy for the general informational categories of scrub, broadleaf forested, needleleaf forested, mixed forested ecotypes associated with these areas. Study plots in the Jarvis Creek control area control site were selected using these maps.

Landsat 7 ETM+ images were reviewed using the USGS Earth Explorer web site (<http://edcns17.cr.usgs.gov>) using Latitude and Longitude coordinates (NW corner – 147.04.00W, 64.20.00N and SE corner – 145.23.00W, 63.39.00N) to obtain a listing of

metadata records for all available imagery of the area. Candidate images were reviewed based on the lowest available aggregate cloud cover and acquisition dates from June to early September to maximize temporal variability of vegetation growth for as many of the potentially present vegetation classes while at the same time avoiding snow cover at higher elevations. Additionally, the image had to be recent acquired (i.e., no more than 2 years old) in order to maintain a high degree of mapping confidence. A Landsat 7 ETM+ scene of the area taken on 10 September 1999 (path 67, row 15) with zero aggregate cloud cover was obtained through US Army Space Command (ARSPACE) Remote Sensing unit in Colorado Springs, Colorado and the Topographic Engineering Center, Fort Belvoir, Maryland.

Reference data for Fort Greely, Alaska was obtained from the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL), in Hanover, New Hampshire. They provided a draft report titled, "An Ecological Land Survey for Fort Greely, Alaska" authored by Jorgenson et al. (2000). Their field data was collected between 1996 and 1998 and consists of 253 surveyed reference points and 126 surveyed verification points that describe the major cover types found on the Fort Greely reservation.

The image file was copied from the CDRoms to a working directory. Using ERDAS Imagine 8.4, the image was display in viewer window. Header records, file statistics and histograms showed that the image was properly georectified. The scene was subsetting to capture the area of interest the Fort Greely reservation. At this point, no enhancement was made to the image to preserve the spectral reflectance characteristics of the pixels. The scene had cloud cover and cloud shadow in the southeastern portion of the image centered over the Washington impact area (Appendix A).

A supervised classification of the scene was made using the reference and verification data generated by CRREL (Jorgenson et al., 2000). Reference point data was converted into an Arcview cover, which was then brought cover into the Imagine viewer. Attribute information was obtained for each reference point using the same cover in an Arcview 3.2 environment. Using the Imagine region-growing tool for all seed pixels (Area constrained = 100 pixels and Euclidean Distance = 20), pixels were selected that corresponded to the appropriate cover type. These seed pixels were then used to grow training polygons of similar spectral reflectance. This procedure was repeated for all of the usable reference points. For significant cover types without reference points (e.g. bare exposed rock, glacier, snow, road, agriculture) training polygons were delineated based on a manual image interpretation of CIR composites of the September scene.

Informational categories are listed below:

Level 1 Classification	Level 2 Classification
Water	<ul style="list-style-type: none"> • River • Pond and Lake
Forest	<ul style="list-style-type: none"> • Broadleaf • Needleleaf • Mixed
Scrub	<ul style="list-style-type: none"> • Scrub
Gravel/Pavement	<ul style="list-style-type: none"> • Roads • Bare Exposed Rock • Barrens
Agricultural Land	<ul style="list-style-type: none"> • Agricultural

During this process, there was some overlap of training polygons of different reference classes. A best estimate of which polygon to use based upon a seed pixel's proximity to an edge signature. A polygon whose seed pixel was best encompassed by similar pixels (i.e., farthest from pixels of different color) was retained. Reference points associated with cloud and cloud shadows were not used. Upon completion of the training polygon selection process 68 polygons generated by seed pixels had been obtained along with 12 polygons generated by manual polygon selection for a total of 80 spectral classes. A maximum likelihood algorithm was used to classify the whole image based on the 80 training spectral classes. A signature separability analysis was performed on the spectral classes using the transform divergence method for all 1-6 bands of information. This generated 2,926 pair-wise comparisons. Using the best average separability and a cut off score of 1,200 (out of a possible 2,000) spectral classes that were similar were merged and poor signatures deleted bringing the training signatures down to 43 spectral classes. Like cover classes (e.g. Scrub 1 + Scrub 2 + ... Scrub *i*, etc) were then combined based on histogram evaluations using a recode process resulting in mapping set of 21 cover classes. Finally, these cover classes were recolored to better distinguish patterns. The classified image was processed with a 5X5-majority filter, which greatly enhanced its appearance (Figure 4).

From the maps of sampling areas of interest, over 100 one-hectare size discrete (i.e., non-overlapping and homogenous) sampling plots, including 15 per ecotype, were identified using a random point generator within ERDAS Imagine 8.4. These sampling plots doubled as verification points. The recommended number of verification points for large area classification should be approximately 50 per ecotype (Jenson, 1996). However, this represents an enormous sampling effort and may be significantly more than required due to the relatively small sampling area of the Jarvis Creek control area. Jenson (1996) suggests that the total number of verification points can be estimated by the formula for the binomial theory:

$$N = \frac{Z^2 (p) (q)}{E^2} \quad \text{where,}$$

Z is the standard normal deviate for the 95% two-sided confidence interval,

p is the expected percent error,
 $q = 100-p$ and
 E is the allowable error.

For this study, $Z = 1.96$, $p = 85\%$, $q = 15\%$, and $E = 10\%$ yielding an $N = 49$ points. This minimum number then would be allocated across the ecotypes of interest as well as any other cover type of mapping interest (e.g., open or barren areas). Using three ecotypes (i.e., scrub, broadleaf, and mixed) and a cover type representing gravel barrens and gravel roads, this equates to approximately 12 verification points per cover type which as mentioned above are the sampling plots. These sample plots were circular with a radius of 55 m for an area of one-hectare.

Phase 2: Soil Sample Collection

Central to the sampling effort is the recognition that measurements of environmental phenomena such as soils or the presence or absence of a contaminant are generally characterized by great variability. In an attempt to limit variability and the associated uncertainty, as well as reduce the number of required samples, CRREL has developed a composite sampling protocol (Ramsey, 2001, personal communication). This method involves collecting numerous (i.e., fifty) incremental samples from a given area, compositing these incremental samples into one well mixed sample, then using this well mixed sample for all laboratory analysis to achieve a substantial reduction in the realized variability of the data set. Since contamination is relatively more variable than measures of soil component characteristics, a composting sampling approach should work well for soil property and subsequent soil quality assessment. Therefore, all field sampling for this research project employed this approach. Field sampling consisted of two investigations:

Investigation 1 – Control Area Characterizations:

The purpose of this investigation is to determine baseline levels of soil quality distribution related to undisturbed ecotypes (Scrub, Broadleaf Forest, and Mixed Forest) referred to in Research Hypotheses 1. Needleleaf Forest ecotype was not sampled due to limited field time, however nine plots was reconnoitered for verification purposes. As described above, the thematic classification for the control area along with a random start point generator was used to determine discrete sampling plots in the control site. Sampling plots were located and marked using a Garmin III+ GPS receiver. Each sample consisted of fifty randomly collected 40 gm incremental samples that were composited into one 2 kg soil sample for that particular plot. Samples were collected from the interface of the organic and mineral strata of the soil profile (i.e., the "O" and "A" layers respectively) within a 55-meter radius of the marked point (Figures 5a and b). These samples were air dried, sieved through a 4 mm mesh, mixed well, double bagged in plastic bags and submitted to the CSU Soils Laboratory. At each sampling plot the depth of the cumulative organic matter was determined by digging a small trench to the depth of the lowest organic horizon or 40 cm which ever was deeper. Additionally, elevation, slope and aspect, and vegetative cover descriptions were noted for each plot.

Investigation 2 – Physical Disturbance in Washington Impact Area:

The purpose of this investigation is to determine soil quality in disturbed ecotypes and to characterize soil quality distribution around impact craters referred to in Research Hypotheses 2.

The sampling area around an impact crater consisted of five concentric rings radiating incrementally outward from the center of the target (Figures 6a and b). The incremental distance (I) from the target array will be determined by dividing the diameter (D) of the observed disturbed area by five (i.e., $I = D/5$) creating five concentric rings. These four points are the sampling locations for each ring. Within each of these rings, twenty 40 gm incremental samples were collected from the top 2 cm of the soil surface. These $4 \times 15 = 60$ sub-samples will be composited into one 2.4 kg soil sample for that particular sample ring. These samples were air dried, sieved through a 4 mm mesh, mixed well, double bagged in plastic bags and submitted to the CSU Soils Laboratory. Finally, elevation, slope and aspect will be noted for each target array.

Phase 3: Soil Sample Processing, Laboratory and Statistical Analysis

Standard methods were used to analyzed soil samples and are described in Table 3. Soil data and descriptive statistics is at Appendix C.

Investigation 1 – Data and Analysis

Twelve one-hectare composite samples were taken from each of the four undisturbed ecotypes (i.e., Washington Control are scrub ecotype and Jarvis Creek control area scrub, broadleaf, and mixed forest ecotypes). A series of random duplicate samples were evaluated to determine if there were significant differences in both sampling method and laboratory analysis. Statistical analysis focused on detecting significant differences between mean % organic matter and pH of paired ecotypes. Tests were performed using two-sample t-Tests assuming unequal sample population variances and utilizing an $\alpha = 0.5$.

Investigation 2 – Data and Analysis

Data and descriptive statistics for the crater ring characterizations can be found at Appendix D. Six craters were sampled. Replicates were visually evaluated based on error bars derived from a 95% confidence interval of their means. Statistical analysis of the rings focused on detecting significant differences between mean % organic matter of paired rings. Tests were performed using two-sample t-Tests assuming unequal sample population variances and utilizing an $\alpha = 0.5$.

Results and Discussion

Land Cover Classification RS/GIS Accuracy

Based on vegetative growth patterns, the classified image that appeared to satisfactorily classify cover types. The classified image appeared to emulate the transitions between river, barren, scrub, mixed forested, broadleaf forested, and needleleaf forested areas, and it seemed to accurately classified lakes and ponds and agricultural areas. Overall classification accuracy was 78.3% (Table 4). However, classification of three of the four riverine ecotypes was exceptionally accurate. Mapping of Scrub, Broadleaf and Mixed Forest ecotypes resulted in 100%, 90% and 89% User's Accuracy respectively and the Kappa statistics describing classified verses reference data were equally as good. Needleleaf Forest ecotype was not accurately classified due to confusion with the other three ecotypes. This was most probably due to verification interpretation of the dominant canopy present during sampling. Of note was the classification's ability to map scrub ecotype (User's Accuracy of 100%), which is the predominant ecotype of the Washington impact area and of other impact areas on Fort Greely.

This classification's usefulness may only extend to riverine settings since the preponderance of the verification points fell within riverine ecotypes. Also, the classification process grouped two or three forms of ecotypes (e.g., level 3 classification of three types of scrub vegetation) which could possibly have been labeled in further detail had additional information been available. Even so, this method may still be appropriate for impact area soil quality evaluations in other settings as long as larger scale ecosystem components such as physiography are held constant.

The use of remotely sensed data in the form of Landsat 7 ETM+ coupled with computer aided analysis for classification into a geographic information system appears to be a viable method of determining ecotype in a riverine setting. When soil quality is correlated with ecotype, it should be a practical method of inferring soil quality through the use of remotely sensed data for situations in which large inaccessible areas must be evaluated. Therefore, it should be of significant value in determining soil quality for similar investigations.

Indicators of Soil Quality

A summary of statistical tests and results is at Table 5. Since adsorption and chelation are directly related to cation exchange capacity (CEC), and CEC is a function of the colloidal content contributed by both organic matter and clays, a regression of CEC on both % organic matter and % clay was performed to determine which was the dominant contributor. CEC proved to be highly correlated to % organic matter with 77% of the variability in CEC represented by % organic matter within the control areas and with 86% of the variability in CEC represented by % organic matter within the impact

area. Clay was not correlated with CEC. Therefore, % organic matter was used to evaluate soil quality. Additionally, soil pH affects CEC, so it too was used as an indicator of soil quality.

Soil Quality Characteristics of Undisturbed Ecotypes

Statistical analysis of the Jarvis Creek control area ecotypes showed no evidence that % organic matter or pH was different among these ecotypes (Table 6). However, there may be soil quality variables that co-vary within ecotypes that may be used to detect significant differences between them. The Washington Range control area scrub ecotype % organic matter and pH were significantly different from each of the Jarvis Creek control area ecotypes. These results indicate that there may be a significant difference in the soil quality of the Jarvis Creek control area ecotypes and Washington Range control area scrub ecotype. This may have implications for the use of remotely sensed ecotype spectral signatures in assessing soil quality, but the results may have been better if the Washington range and impact areas were included in the classification process. Also, a level 3 classification may have resulted in better discrimination between different vegetative forms within ecotypes (e.g, differentiating between a scrub ecotype dominated by *Dryas drummondii* and one dominated by *Populus balsamifera* saplings). Soil quality differences between these forms may then be more pronounced.

Soil Quality Characteristics of Undisturbed and Disturbed Ecotypes (Craters)

Comparison of undisturbed Washington Range control area scrub to the Washington Impact area scrub showed no significant differences in % organic matter and pH. There was a significant difference between soil quality of craters and sampled plots within the impact area as well as a significant difference between soil quality of craters and Washington Range control area scrub. Statistical analysis of the crater ring replicates showed that both sampling technique and laboratory analysis appear to be consistent and reasonably precise (Figures 7a-f). Soil nutrient values are the most variable, but key measures of adsorption capacity (i.e., CEC and pH) are very consistent. Data analysis shows that as one moves from the center of the crater to the outer most sampled ring there is a significant gradient of soil quality characteristics (Table 7). While adjacent rings do not show significant differences in % organic matter, there is a significant difference between rings 1 & 3, 2 & 4, and 3 & 5. This difference is apparent in graphs of % organic matter verses distance from the crater center (Figure 8 a-f).

This analysis shows that cratering is a significant physical disturbance within the impact area. If the frequency and intensity of this physical disturbance exceeds the capacity of the system to recover, the system may reach a threshold from which both recovery and capacity for contaminant attenuation is lost. Whether the disturbance regime has or will reach a critical resiliency threshold can be evaluated by comparing

crater age. Relatively higher concentrations of organic matter were found in the center of craters that were four years or older. This is a reasonable finding given the nature of the soil forming processes at work in the Washington Impact Area. Craters provide a depression that can capture wind blown leaves, silts and finer organic particulates, as well as seeds. They may also capture snow and serve as a moisture source for plant establishment. Most of the craters sampled had small balsam poplar saplings at their center (used to approximate the age of the craters). It appears that the physical disturbance and displacement of soil material eventually serves as a catalyst for organic matter additions assisting recovery. Also, the % organic matter of the surface soil appears to recover as shown by the flattening of the gradient curve on older craters.

Conclusion

Follow-on Analysis

A principle component analysis of soil properties may provide greater insight into other important ecotype associated soil properties. While the statistical methods used in this analysis did not detect a significant difference in the soil quality of undisturbed Jarvis Creek control area ecotypes for % organic matter, a principle component analysis may provide better resolution of differences. Also, the data may be better suited for non-parametric analysis.

CRREL gathered munitions contamination data for the Washington Impact Area during the same period this study gathered soil quality samples. Many of the CRREL samples were superimposed over soil quality sampling. The CRREL data should be available in early 2002. Again, utilizing a principle component analysis and non-parametric methods of analysis may yield additional findings. If contamination can be correlated with soil quality, in particular to an indicator such as % organic matter which appears to be a reasonably consistent metric across all sampling done in this study, then it may be possible to rate a given soil for its resilience and attenuation ability.

Development and Use of Soil Organic Matter Resiliency Metric

The soil component performs the following functions: provides habitat for soil microorganisms, serves as an engineering medium and structural support for plants, acts to filters water resources, and serves as a nutrient bank for vegetation (Bradey and Weil, 1999). Quality soils have been described by their soil organic matter. Soil organic matter (SOM) is a principal element of the soil component affecting all of the above. SOM enhances microbial functions increasing energy flux and rate of nutrient cycling, which in turn aids degradation of organic compounds resulting in less soil and water pollution and greater plant production. SOM is the source of humic substances that can increased a soil's buffer capacity resulting in a more stable soil pH. SOM can increase water-holding capacity, which provides for greater plant production. SOM is the source

of non-humic substances that can increase aggregate stability, which means less soil erosion and less soil and water pollution. These same non-humic substances can provide increased adsorption and metal chelation capacity enabling the soil component to retain organic and inorganic pollutants, which also contributes to less soil and water degradation.

It is these properties, and in particular SOM's ability to influence the fate and transport of contaminants through an ecosystem, that provides the basis for future work. If one can characterize the distribution of SOM, predict its dynamics, and ascribe measures of its attenuation potential, then the implications for adaptive ecosystem management in the face of evolving contaminant threats may be profound. Resource managers and environmental scientists could adapt their activities to maximize this potential thereby mitigating or avoiding disturbances that are beyond an ecosystem's resistance and resilience capability.

Agricultural practices such as tillage, fertilization, pesticide application and cropping have been universally recognized as anthropogenic disturbances of varying degrees affecting ecosystem productivity. SOM is central to understanding the effects of these practices. This agricultural scenario can readily be adapted toward range and impact area ecosystem management. Recently, the National Research Council, (2000) has proposed that SOM should be widely recognized as an indicator of soil quality and productivity because of its ability to:

- provide a nutrient and energy source for soil biota
- improve soil structure by strengthening soil aggregates
- increase water holding capacity
- promote infiltration and reduce erosion
- increase cation exchange capacity
- chelate metals
- influence the fate and transport of pesticides

Also, SOM is considered the single most important indicator of soil health (Larson and Pierce, 1994). SOM measurable attributes are listed in Table 8 (Fenton et al, 1999). They provide a sensitive measure of SOM's contribution to an ecosystem's soil function.

Means of Simulating Soil Organic Matter Dynamics

Once SOM for a particular system is characterized it can then be readily modeled and used as a resiliency metric. The next step in exploring ecosystem resilience in the face of munitions disturbance is to use SOM dynamics output, or the fluxes in SOM pools as a result of natural and anthropogenic driving variables, to provide an established metric for determining an ecosystem's response to various management practices. The findings of this study should enable effective parameterization of such a simulation.

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Tables, Figures and Appendices

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2	Munitions Expenditures
3	CSU Soil Lab Methods
4	Classification Accuracy Matrix
5	Summary of Statistical Analysis
6	Undisturbed Ecotype Analysis
7	Crater Ring Analysis

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2	Sample plot scaling
3	Climate Graph
4	Jarvis Creek Control Area Classification
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B	Munitions Disturbance
C	Soil Data
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Table 1. Notional Range Requirements for US Army Installations (TC 25-8). Target and target array calculations are based on ranges descriptions in TC 25-8.

Range No*	Range Type	Firing Unit Size	Maximum Position Points or Lanes per Range	Army Range Objectives	Division**			Modified	
					Armor	Mech	Inf	No Targets or Target Arrays per Point or Lane	No Targets or Target Arrays per Range
6-1	OPQC/MPFQC	CO	15	Required	1	1	1	7	105
6-2	Multipurpose Indoor Range	CO	Throughput Dependent	Optional					
6-3	Basic 25 meter Zero	CO	110	Required	2	2	2	1	110
6-4	Automated Field Fire	CO	32	See Note	***	***	***	3	96
6-5	Automated Record Fire	CO	16	See Note	***	***	***	7	112
6-6	Modified Record Fire	CO	16	See Note	2	2	2	9	144
6-7	Sniper Field Fire	PLT	4	Optional	1	1	1	12	48
6-8	Night Fire (Small Arms)	CO	35	Optional	1	1	1	2	70
6-9	Known Distance	CO	55	Optional	2	2	2	1	55
6-10	Machine Gun 10 meter	CO	20	Required	2	2	2	1	20
6-11	Multipurpose Machine Gun Transition	CO	10	Required	1	1	1	12	120
6-12	Multipurpose Gunnery Range	CO	6	TBD	1	1	1	7	42
6-13	Hand Grenade Familiarization Course	CO	4	Required	1	1	1	4	16
6-14	Hand Grenade Qualification Course	CO	6	Required	1	1	1	7	42
6-15	Grenade Launcher	CO	4	Required	1	1	1	7	28
6-16	Recoilless Rifle	CO	8	Optional	1	1	1	7	56
6-17	Light Antitank Weapon	CO	8	Optional	1	1	1	1	8
6-18	Scaled Range (1:30/1:60)	CO	4	Optional	1	1	1	10	40
6-19	Scaled Gunnery Range (1:5/1:10)	CO	4	Optional	1	1	1	10	40
6-20	Stationary Gunnery	CO	14	Optional	2	2	1	1	14
6-21	Antiarmour Tracking and Live Fire	CO	20	Required	1	1	1	0.5	10
6-22	Light Demolition	CO		Required	1	1	1	6	6
6-23	Infiltration Course	CO	2	Optional	1	1	1	0	0
6-24	Bayonet Assault Course	CO	4	Optional	1	1	1	10	40
6-25	Target Detection (Non-firing)	CO	50	Optional	1	1	1	0.2	10
6-26	MOUT Assault Course (MAC)	CO	8	Required	1	1	1	1	8
6-27	Gunship Harmonization	CO	1	Optional	1	1	1	1	1
6-28	Flame Operations Range	CO		Optional	1	1	1	6	6
6-29	Mortar, Scaled	CO	6	Optional	1	1	1	2	12
6-30	Mortar	CO	6	Required	1	1	1	5	30
6-31	Field Artillery, 1:10 Scaled	BTRY	Optional	Optional	1	1	1	5	30
6-32	Field Artillery Indirect Fire	BTRY	Optional	Required	1	1	1	5	30
6-33	Multipurpose Training Range	CO	2 Trails	Required	2	2	1	20	40
6-34	Combat Engineer Vehicle	CO		Required				22	22
6-35	Air Defense Firing	BTRY		Optional	0	0	0	2	12
6-36	Helicopter Gunnery	CO	8	Required	1	1	1	3	24
6-37	Fire and Movement	CO	Throughput Dependent	Optional	1	1	1	6	24
6-38	Squad Defense Range	CO	5	Optional	1	1	1	6	30
6-39	Infantry Squad Battle Course	SQUAD		Required	1	1	1	20	20
6-40	Infantry Platoon Battle Course	PLT		Optional	1	1	1	60	60
6-41	MPRC-H+	PLT		Required	1	1	1	60	60
6-42	MPRC-L+	PLT		Required			1	60	60
6-43	Platoon Defense Against Aircraft	BTRY		Optional	0	0	0	NA	NA
6-44	MOUT CTF++	CO/BN	16/32	Required	1	1	1	NA	NA

* Range numbers correspond to those in Chapter 6, TC 25-8

** Notional quantities by range type depend on annual training frequency. The most current DA PAM 350-38 prescribes training frequency.

*** AFFs and AFFs are recommended for TRADOC school installations. MFRs are recommended at unit-based installations to conserve resources.

+ Type and configuration of MPRC selected depend on which units are supported (armour/mechanized division = MPRC-H; LID, air assault division = MPRC-L).

++ AC division installations typically need a MOUT complex consisting of a 32-building CTF with MOUT assault course to meet throughout METL training requirements. AC separate brigade, semiactive installations supporting RC annual training and weekend training typically need a MOUT complex consisting of a 16-building CTF with MOUT assault course.

Table 2. Summary of area determinations and potential contaminant loading rates.
 Tabular data can be found at Appendix B.

	Acre	Hectare
Ft Greely Installation Area	662000	267905
Total High Hazard Impact Area	85042	34416
Surface Area of Target Arrays	2409.3	975
Average Area Cratered per Year	25.324	10.25

	Percent Area
% Ft Greely that is High Hazard Impact Area	12.85 %
% High Hazard Impact Area in Use	2.83 %
% Target Array Surface Area Cratered per Year	1.05 %
% High Hazard Impact Area Cratered per Year	0.0298 %

	Loading Rate
Total Mass of Explosive Filler (DUD + LO)	4460 kg
Theo. Max. Explosive Loading Rate TGT Arrays	0.46 g/m2/yr
Theo. Max. Explosive Loading Rate Crater Area	43.52 g/m2/yr

Soil properties:	Methods:	Reference:
pH	Soil to water ratio of 1:1	2, p.487
pH Buffer	SMP Buffer	2, pp.502-505
Conductivity	Soil to water ratio of 1:1	2, pp.420-427
Cation Exchange	Measure Na; account for entrained Na with nitrite.	2, pp.1201-1230
Texture	Hydrometer	1, method 15-4
% Organic Carbon	Modified Walkely-Black	2, pp.995-996
% Organic Matter	1.724 x % Organic Carbon	
Soil Nutrients:		
Nitrogen as ammonia Nitrogen as nitrate	2M potassium chloride extract, automated phenate method by FIA	2, pp.1146-1162
Total N	CHN furnace	2, pp.1085-1122
Total C	CHN furnace	2, pp.967-977
Phosphorous	Mehlich 3 Extract	2, pp.893-894
Potassium	Mehlich 3 Extract	2, pp.893-894
Calcium	Mehlich 3 Extract	2, pp.893-894
Magnesium	Mehlich 3 Extract	2, pp.893-894
Extractable Metals:		
Cadmium	Mehlich 3 Extract	2, pp.893-894
Chromium	Mehlich 3 Extract	2, pp.893-894
Copper	Mehlich 3 Extract	2, pp.893-894
Lead	Mehlich 3 Extract	2, pp.893-894
Zinc	Mehlich 3 Extract	2, pp.893-894

Table 3. List of soil properties, nutrients and metals analysis, and laboratory methods.

Reference:

1. Klute, A. 1986. Methods of Soil Analysis: Part 1. Physical and Mineralogical Methods. Soil Science Society of America, Inc., Madison, Wisconsin.
2. Spark, D.L., (ed). 1996. Methods of Soil Analysis: Part 3. Chemical Methods. Soil Science Society of America, Inc., Madison, Wisconsin.

CLASSIFICATION ACCURACY ASSESSMENT REPORT

ERROR MATRIX

Classified Data	Reference Data				
	Mixed Forest	Scrub	Needleleaf Forest	Gravel Pavement	Broadleaf Forest
Mixed Forest	8	0	1	0	0
Scrub	0	14	0	0	0
Needleleaf Forest	3	4	7	0	2
Gravel/Pavement	0	0	1	9	1
Broadleaf Forest	1	0	0	0	9
Column Total	12	18	9	9	12

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Mixed Forest	12	9	8	66.67%	88.89%
Scrub	18	14	14	77.78%	100.00%
Needleleaf Forest	9	16	7	77.78%	43.75%
Gravel/Pavement	9	11	9	100.00%	81.82%
Broadleaf Fores	12	10	9	75.00%	90.00%
Totals or Average	60	60	47	79.45%	80.89%

Overall Classification Accuracy = 78.33%

KAPPA (K[^]) STATISTICS

Overall Kappa Statistics = 0.7289

Conditional Kappa for each Category.

Class Name	Kappa
Mixed Forest	0.8611
Scrub	1
Needleleaf Forest	0.3382
Gravel/Pavement	0.7861
Broadleaf Forest	0.875

Table 4. Error matrix, Mapping Accuracy and Kappa Statistics for Ecotype Classification

Table 5. Summary of Statistical Tests and Results. Detailed analysis is at Appendix D.

Hypothesis	Test	Results/Remarks
1. and 2. What independent variable (%Organic matter or %Clay) most affects Cation Exchange Capacity (CEC)?	Regression CEC on % Organic matter and %Clay	CEC-OM $R^2=.77$ CEC-Clay $R^2=.009$ Therefore, focus on % OM
1. Is there a difference between undisturbed ecotypes, for broadleaf, mixed and scrub?	t-test on % Organic matter and pH means	No evidence that the Jarvis Creek % OM means are different, Scrub W is different from all Jarvis Creek ecotypes
1. Is there a difference between Washington undisturbed and disturbed scrub?	t-test on % Organic matter means	There is no evidence of a difference.
2. Is there a difference between crater samples and impact area plots, and between crater samples and Washington undisturbed plots?	t-test on % Organic matter and CEC means	Significant difference between % Organic matter means, $p=0.03$ and 0.001 respectively.
2. Is there a difference between crater ring replicates for crater rings?	Graph with error bars for selected analytes	Graphs of crater ring replicates with error bars (Figure 7a and b)
2. Is there a difference between rings for crater averages for crater rings?	t-test on % Organic matter means	Significant difference between means for Rings 1&3, 2&4, 3&5 (Table 7)

Table 6. Undisturbed ecotype analysis. Shaded blocks depict ecotypes for which there is no evidence of a difference between ecotype for % organic matter. "Scrub W" is Washington Range Control Area scrub and "Scrub J" is Jarvis Creek Control Area Scrub.



Summary of t-Tests %OM	Scrub W	Scrub J	Broadleaf	Mixed
No evidence to reject Ho: Means are equal 				

Table 7. Crater ring analysis in which common crater rings were averaged together. Shaded blocks depict rings for which there is no evidence of a difference between rings for % organic matter.














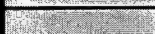




Summary of tests %OM	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
No evidence to reject Ho: Means are equal  					
					
					
					
					
					

Table 8. SOM attributes, measures and environmental effects summarized from (Fenton et al., 1999).

SOM Attribute	Measure(s)	Environmental Effect
Buffer Capacity	Buffer Capacity	Stable pH to aid adsorption
Water Holding Capacity	Bulk Density and Texture	Biomass production
Aggregate Stability	Bulk Density and Texture	Erosion Prevention
Adsorption Capacity	Cation Exchange Capacity and pH	Organic and Inorganic Adsorption
Chelation Capacity	Cation Exchange Capacity and pH	Inorganic Adsorption

Study and Control Areas

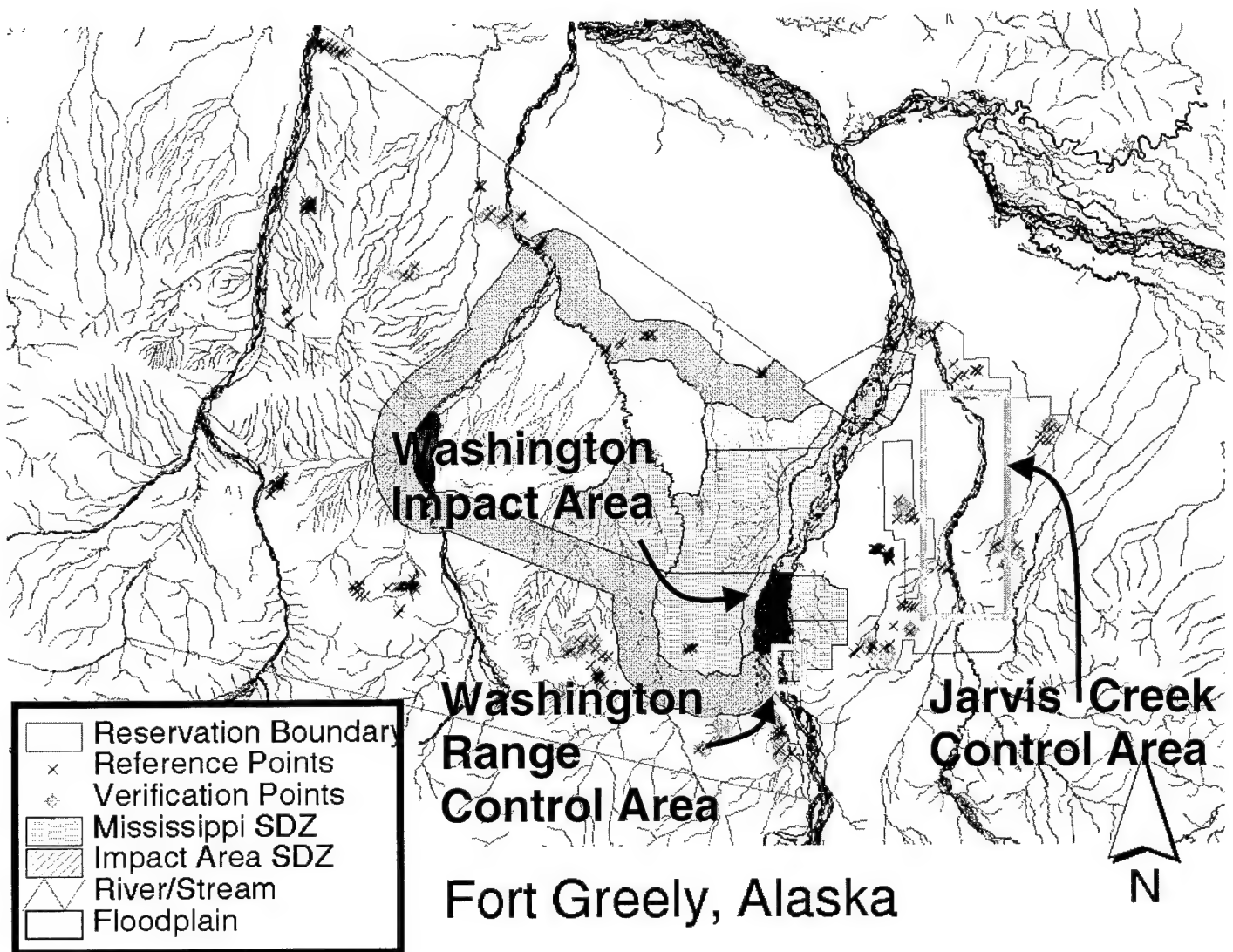


Figure 1. Map of the Fort Greely Reservation depicting the Jarvis Creek and Washington Range Control Areas as well as the Washington Impact Area. Reference and verification points are sampling points described by Jorgenson et al., 2001.

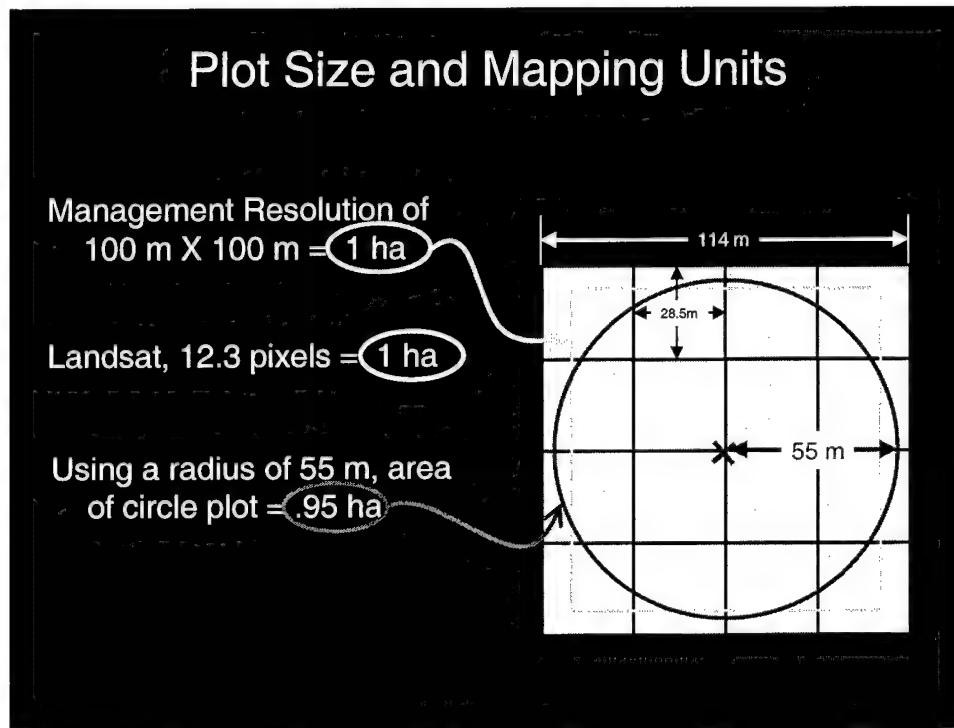


Figure 2. Information management integration of spatial scaling. Management resolution and Landsat multispectral data comparisons yield scale of observation for sampling plots.

Fort Greely, Alaska Climograph

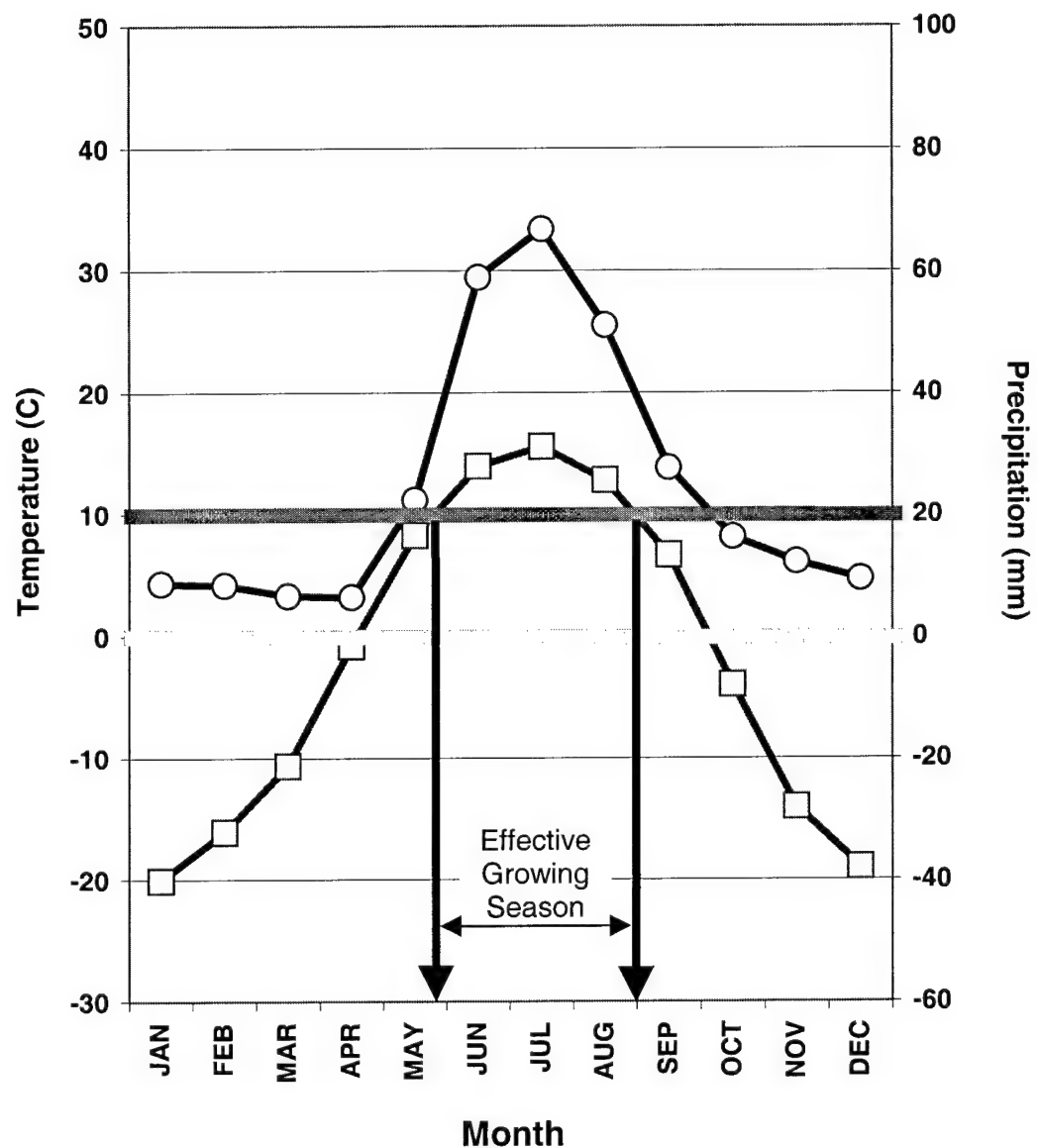
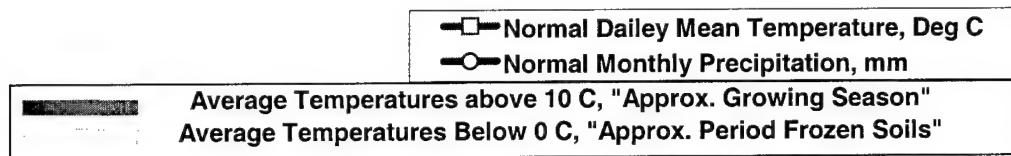


Figure 3. Climate graph for Fort Greely Alaska depicting effective growing season (Diersing et al., 1990). Climate data obtained from Big Delta FAA/AMOS AP, AK (500770). 2001.

Jarvis Creek Control Area

Covertime

Class_Names



Mixed Forest

Scrub



Needleleaf Forest



Gravel/Pavement



Lake



River/Stream



Broadleaf Forest



Sampling Plot

Scale



Meters

Jarvis Creek Control Area
Sampling Plots
NAD 27
UTM 6 N
14 DEC 01

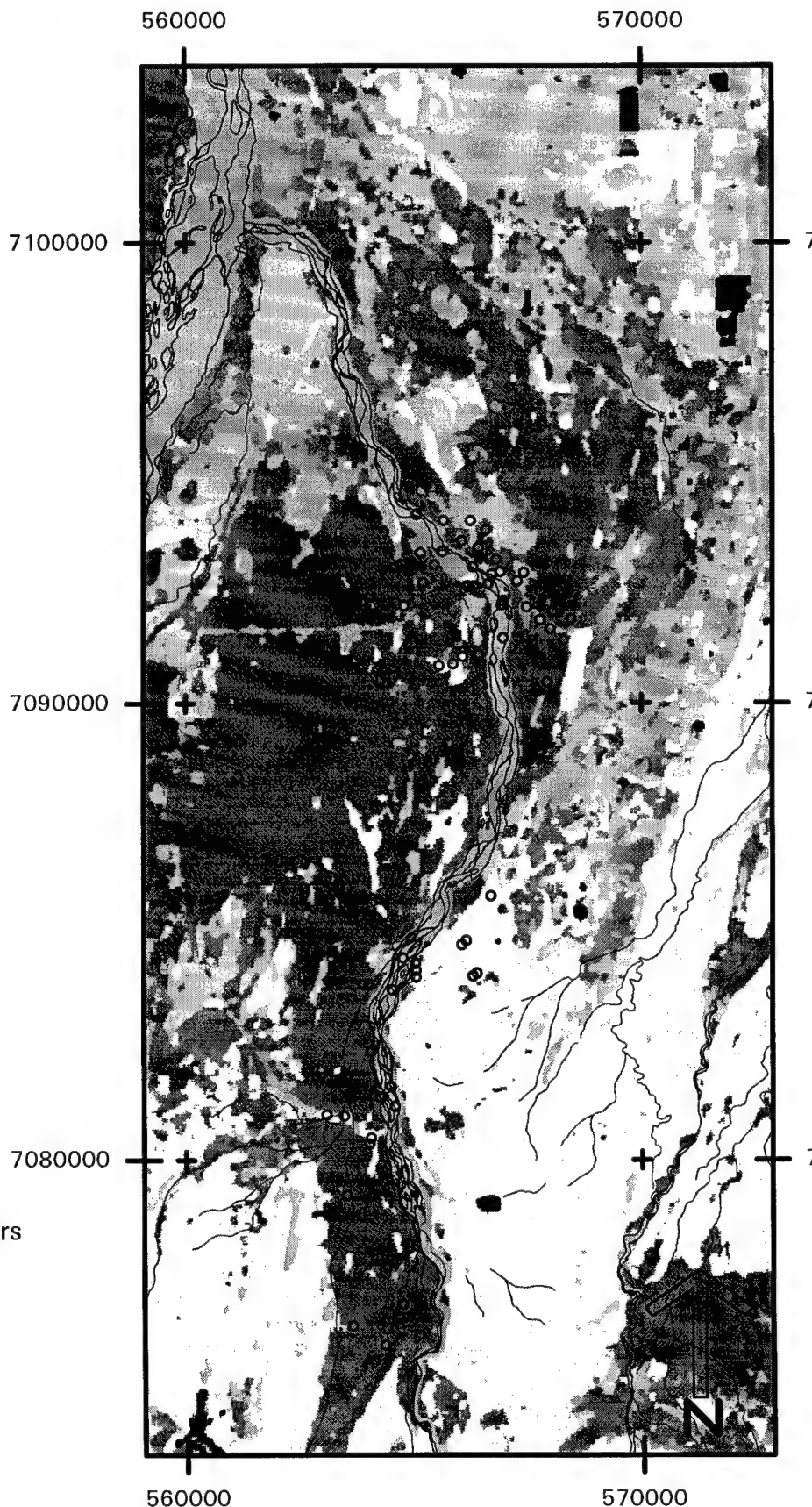
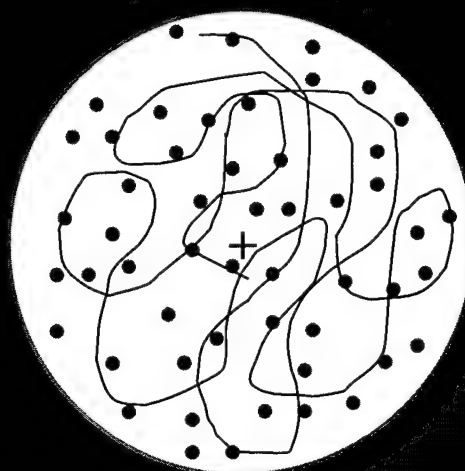


Figure 4. Jarvis Creek Control Area Map with Sampling Plots

Sample Plot Random Walk

- Mark plot center point
- Stay within a radius of 55 meters
- Randomly walk around center point
- Collect fifty 40 g incremental samples = 2 kg sample
- Organic matter depth from center point.



⊙ = incremental sample

Figure 5a. Depiction of hectare plot sampling method using random walk collecting 50 incremental samples for one composite sample.

Sample Collection

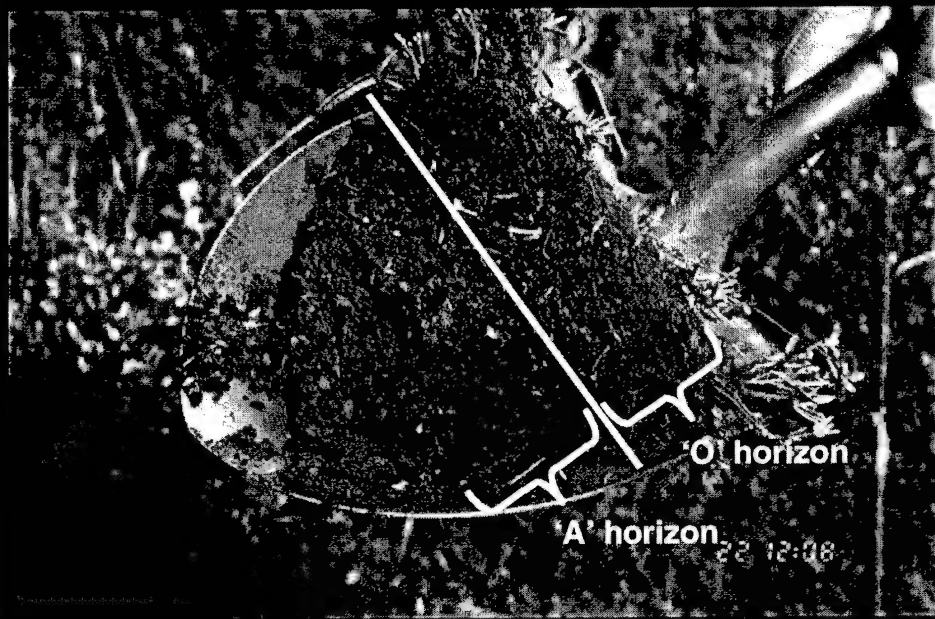


Figure 5b. Example of 'O' and 'A' horizon interface from which soil samples were collected.

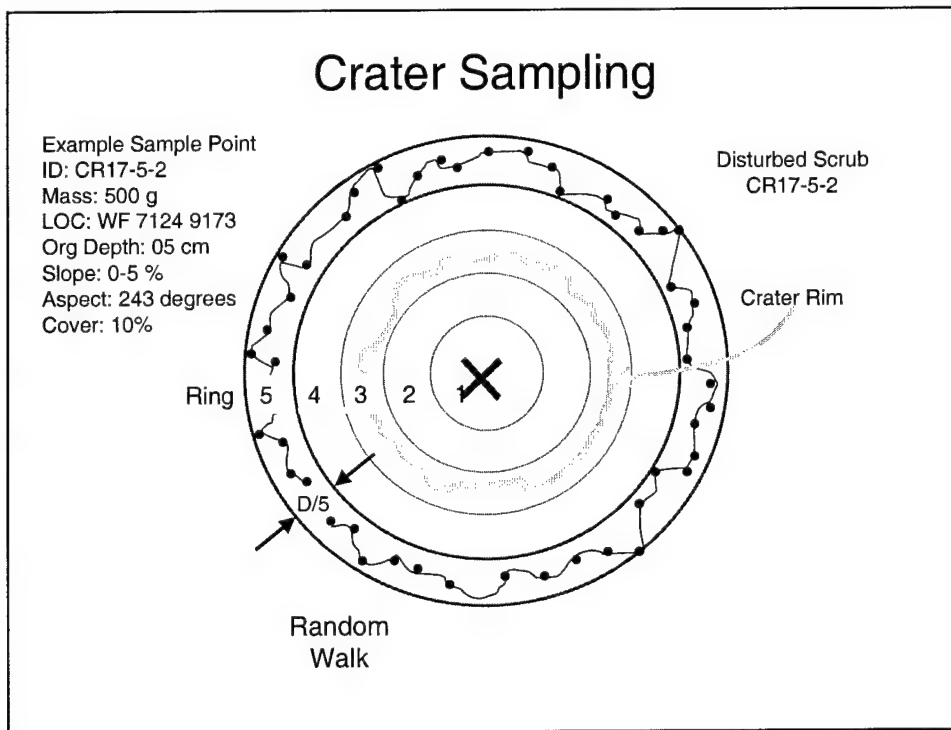


Figure 6a. Depiction of crater sampling method using random walk collecting 20 incremental samples for one composite ring sample.

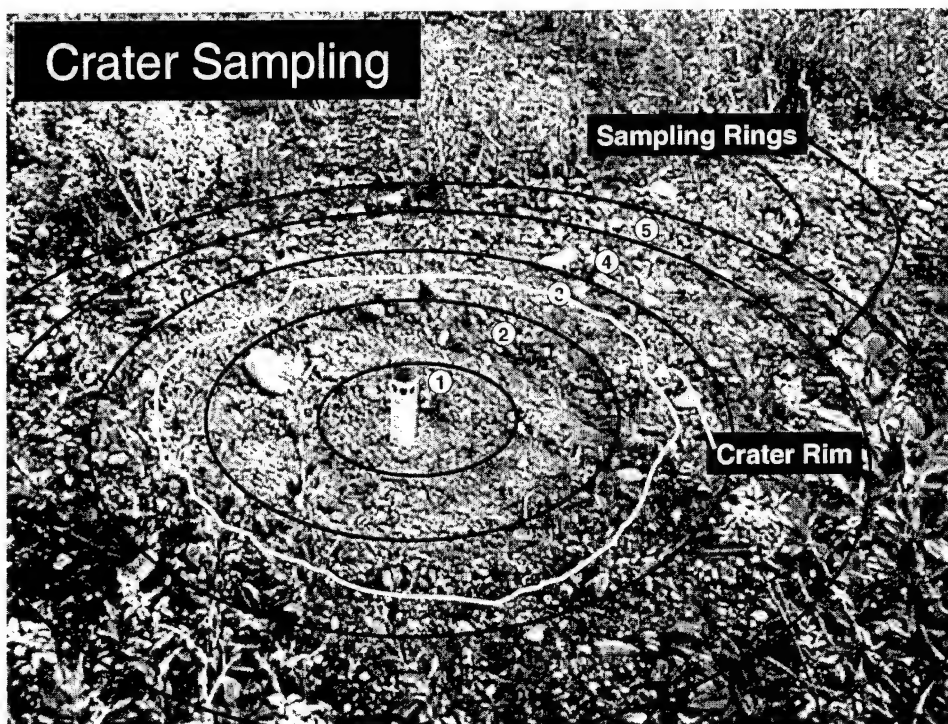
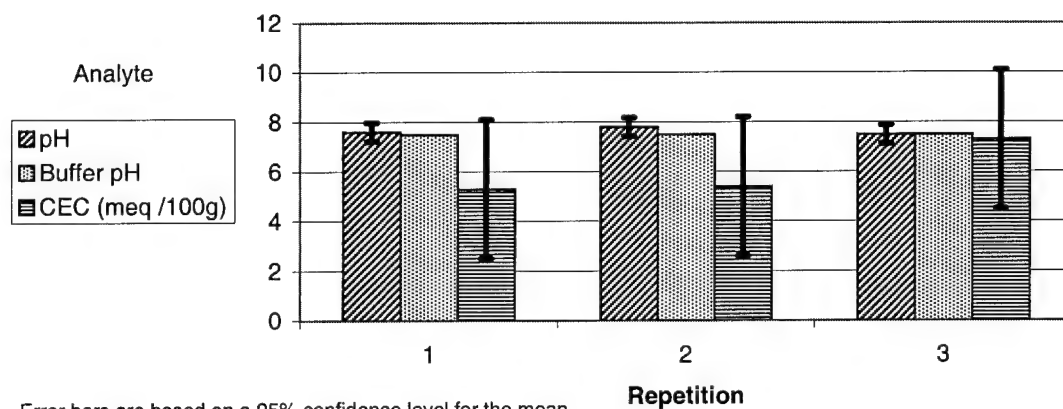


Figure 6b. Actual layout of crater sampling during fieldwork. This is Crater 7 which is estimated to be a 1 to 2 year old 105mm crater.

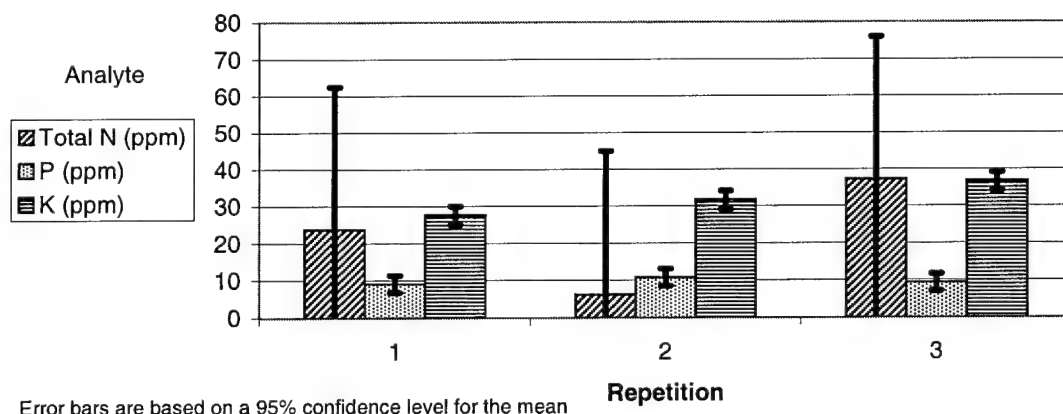
Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 9-3-1	7.6	7.5	5.3	23.8	9.13	27.8	0.043	0.581
CR 9-3-2	7.8	7.5	5.4	6.2	10.8	31.9	0.059	0.827
CR 9-3-3	7.5	7.5	7.3	37.3	9.39	36.8	0.044	0.568
Confidence Level(95.0%)	0.3794586	0	2.799483	38.740099	2.2742298	11.283637	0.0222651	0.3625

Ecotype	Lab #
CR 9	R2187
CR 9	R2188
CR 9	R2189

Crater 9, Ring 3



Crater 9, Ring 3



Crater 9, Ring 3

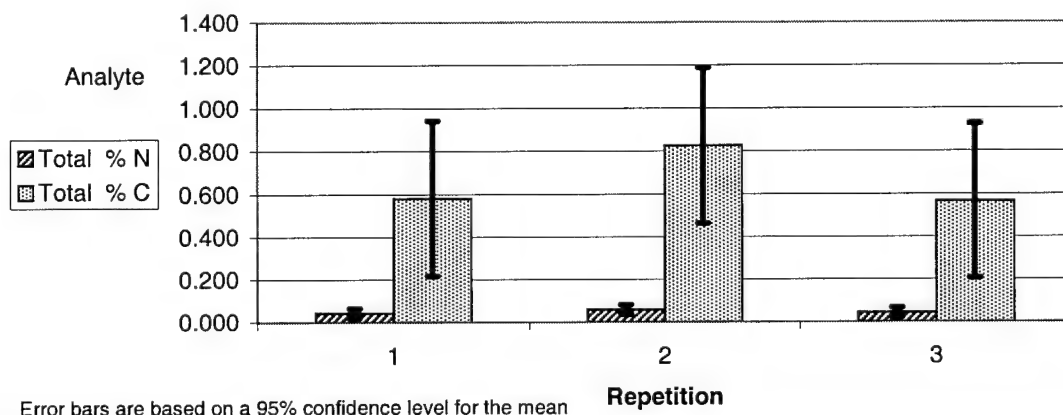
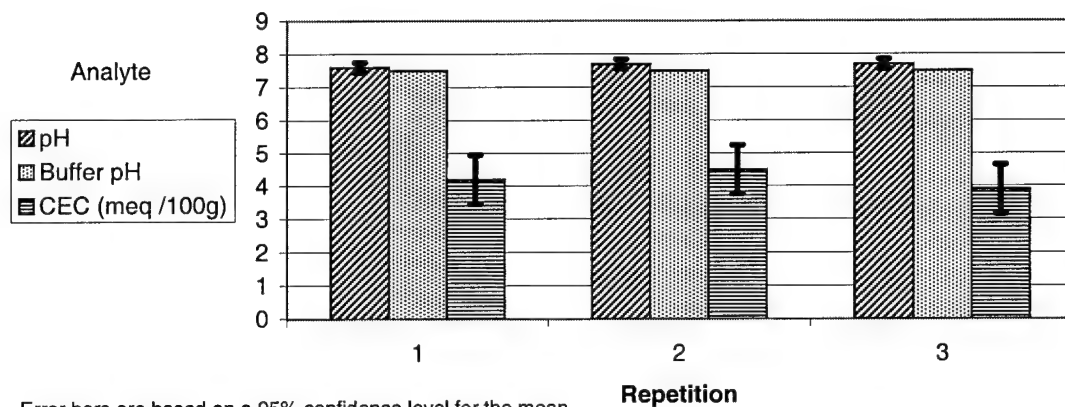


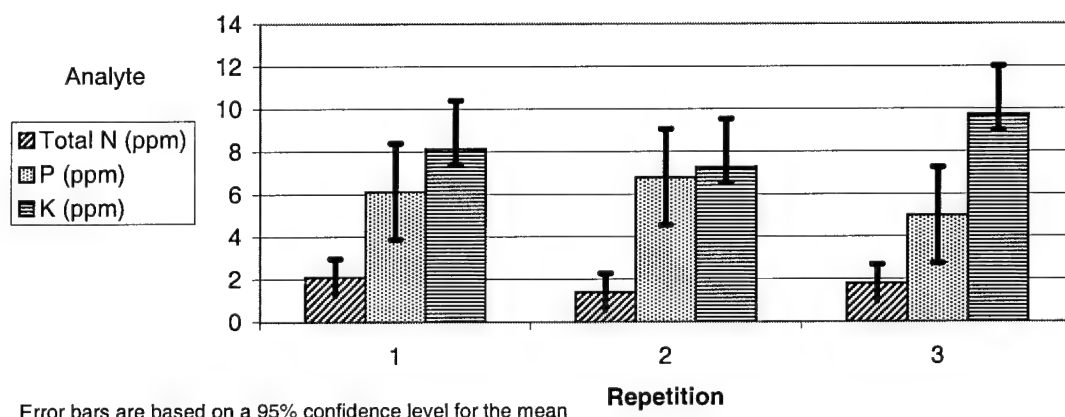
Figure 7a. Crater 9 Ring 3 analysis of replicates.

Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 7-2-1	7.6	7.5	4.2	2.1	6.13	8.1	0.033	0.429
CR 7-2-2	7.7	7.5	4.5	1.4	6.80	7.3	0.023	0.496
CR 7-2-3	7.7	7.5	3.9	1.8	5.00	9.8	0.026	0.348
Confidence Level(95.0%)	0.1434219	0	0.7452418	0.8724011	2.2605619	3.112367	0.0127476	0.1841003

Crater 7, Ring 2



Crater 7, Ring 2



Crater 7, Ring 2

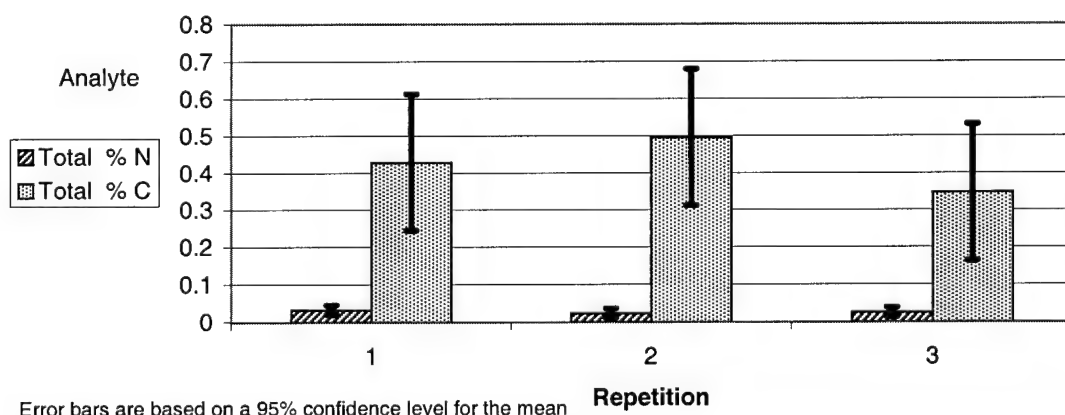
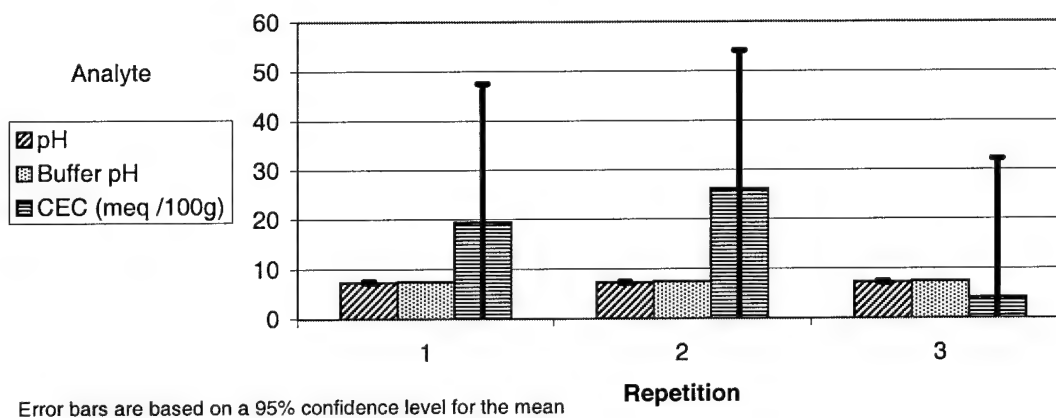


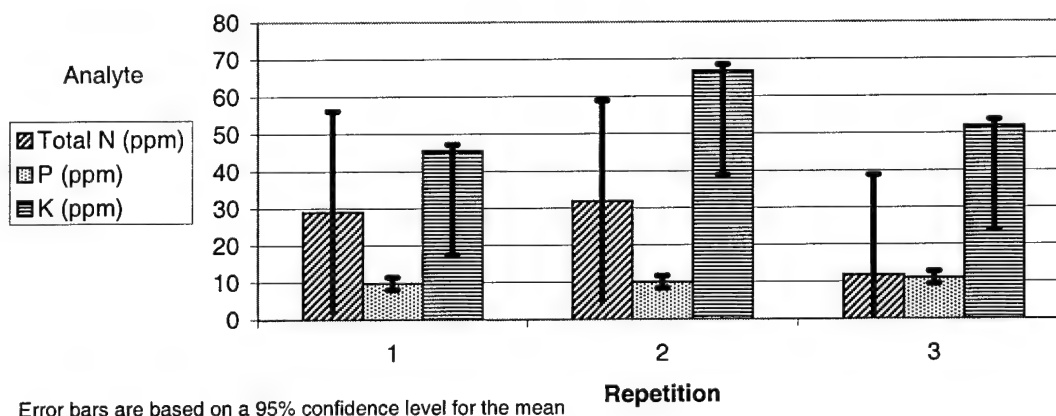
Figure 7b. Crater7 Ring 2 analysis of replicates.

Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 2-5-1	7.4	7.5	19.5	29.1	9.80	45.6	0.157	1.948
CR 2-5-2	7.3	7.5	26.2	31.9	10.1	66.9	0.138	1.768
CR 2-5-3	7.3	7.5	4.2	11.8	11.1	52.0	0.160	2.458
Confidence Level(95.0%)	0.1434219	0	28.012826	27.044434	1.6620236	27.214542	0.0296367	0.8890998

Crater 2, Ring 5



Crater 2, Ring 5



Crater 2, Ring 5

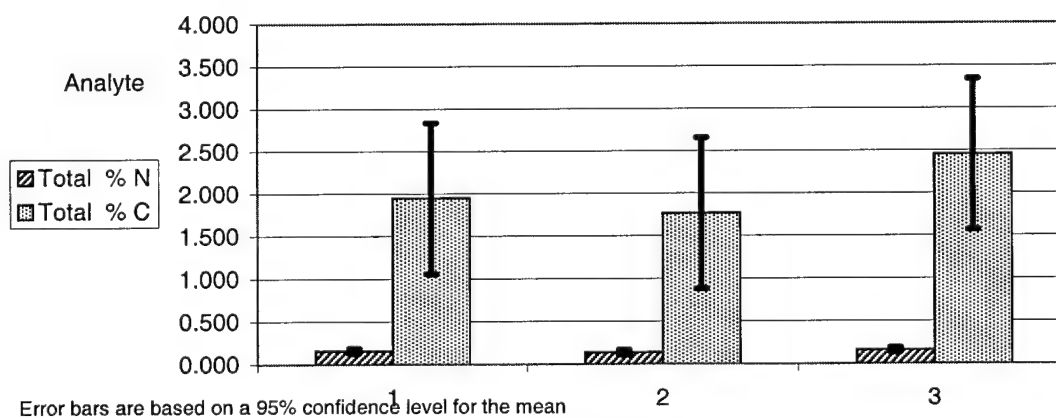
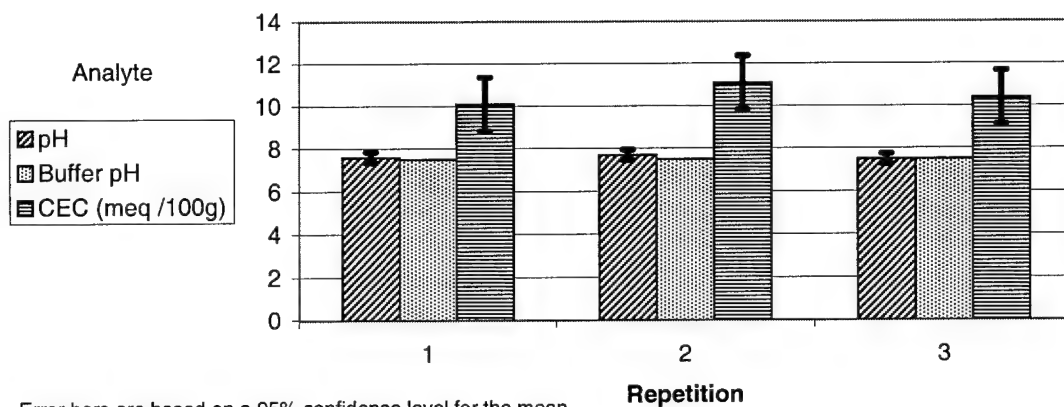


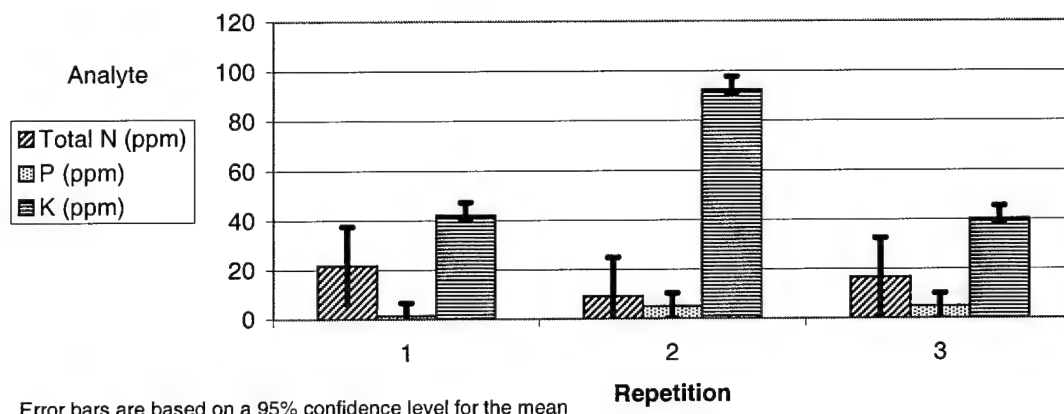
Figure 7c. Crater 2 Ring 5 analysis of replicates.

Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 17-1-1	7.6	7.5	10.1	21.8	1.39	42.2	0.045	0.908
CR 17-1-2	7.7	7.5	11.1	9.2	5.12	92.6	0.049	0.828
CR 17-1-3	7.5	7.5	10.4	16.8	4.91	40.4	0.050	0.831
Confidence Level(95.0%)	0.2484139	0	1.2747614	15.760751	5.2050531	73.601083	0.0065724	0.1126478

Crater 17, Ring 1



Crater 17, Ring 1



Crater 17, Ring 1

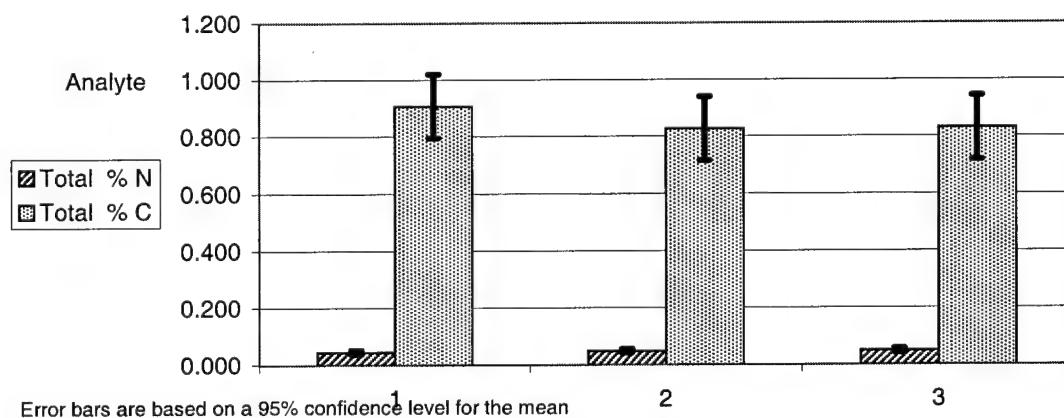
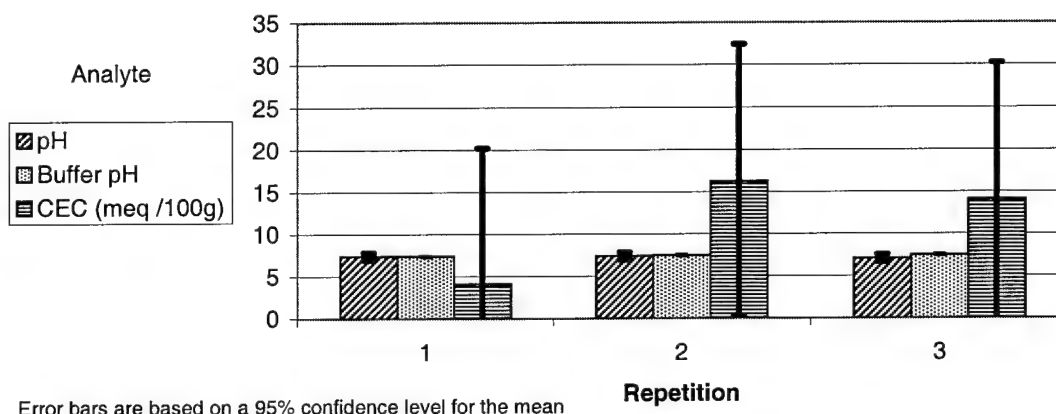


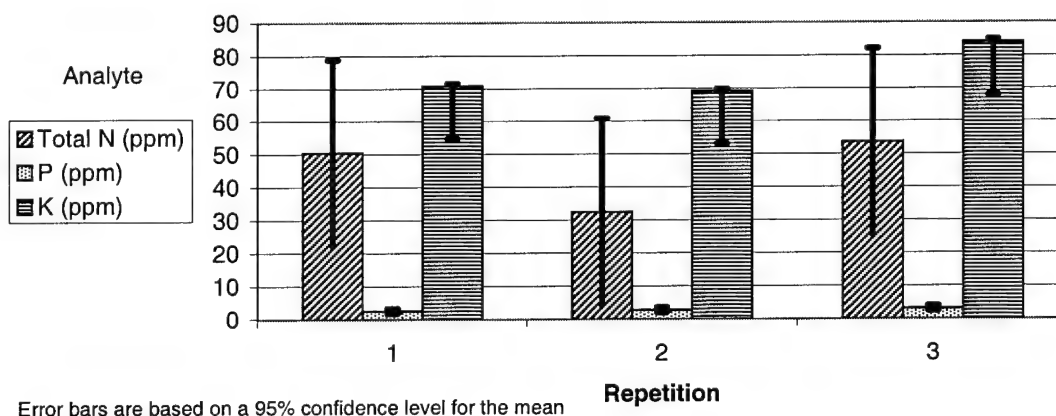
Figure 7d. Crater 17 Ring 1 analysis of replicates.

Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 16-2-1	7.4	7.4	4.1	50.5	2.62	71.0	0.036	0.400
CR 16-2-2	7.4	7.5	16.3	32.5	2.81	69.3	0.112	1.592
CR 16-2-3	7.1	7.5	14.1	53.7	3.22	84.0	0.078	1.121
Confidence Level(95.0%)	0.4302656	0.1434219	16.152638	28.390283	0.7550735	20.098377	0.0945715	1.4913618

Crater 16, Ring 2



Crater 16, Ring 2



Crater 16, Ring 2

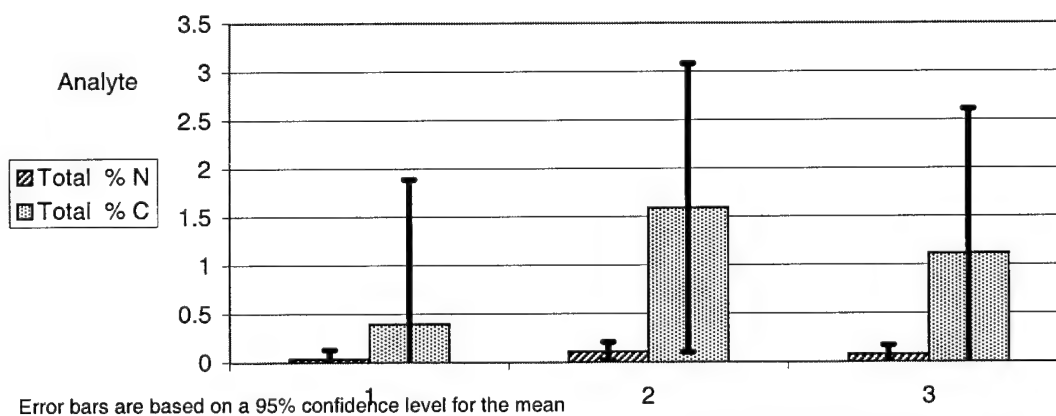
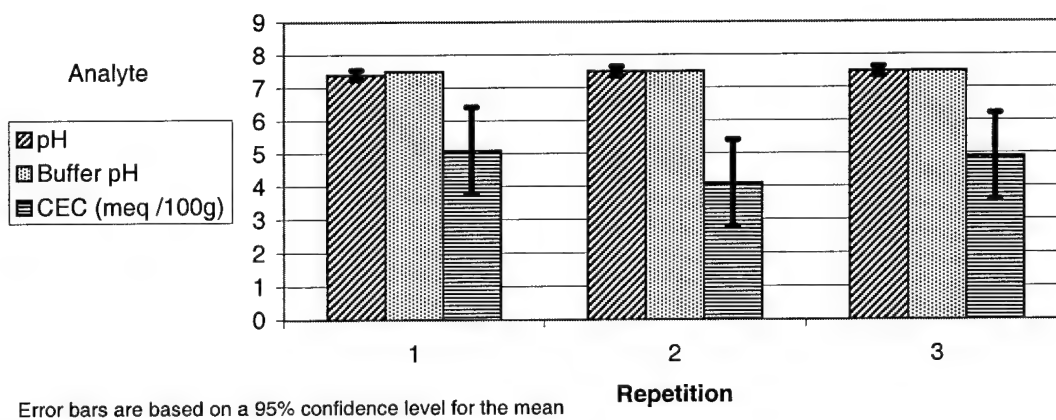


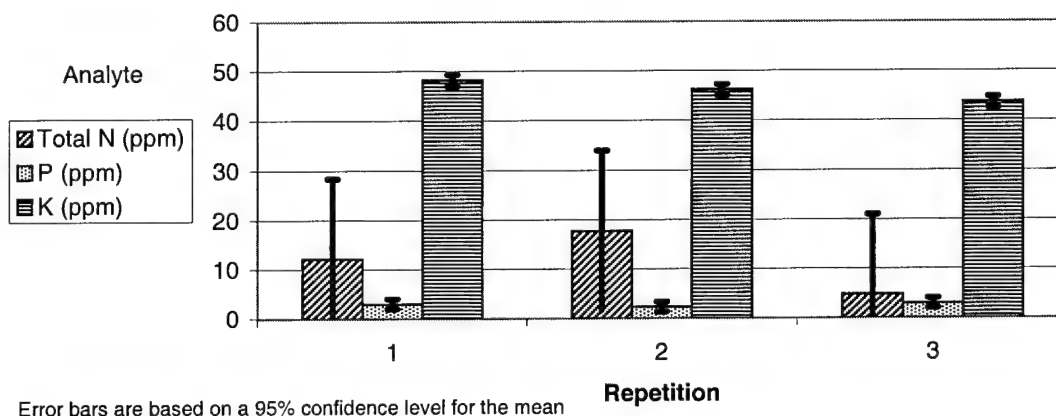
Figure 7e. Crater 16 Ring 2 analysis of replicates.

Sample ID #	pH	Buffer pH	CEC (meq /100g)	Total N (ppm)	P (ppm)	K (ppm)	Total % N	Total % C
CR 15-4-1	7.4	7.5	5.1	12.2	2.99	48.3	0.034	0.590
CR 15-4-2	7.5	7.5	4.1	17.8	2.30	46.3	0.018	0.439
CR 15-4-3	7.5	7.5	4.9	4.8	3.01	43.8	0.044	0.586
Confidence Level(95.0%)	0.1434219	0	1.314483	16.198418	1.0056941	5.6166277	0.0325792	0.2137563

Crater 15, Ring 4



Crater 15, Ring 4



Crater 15, Ring 4

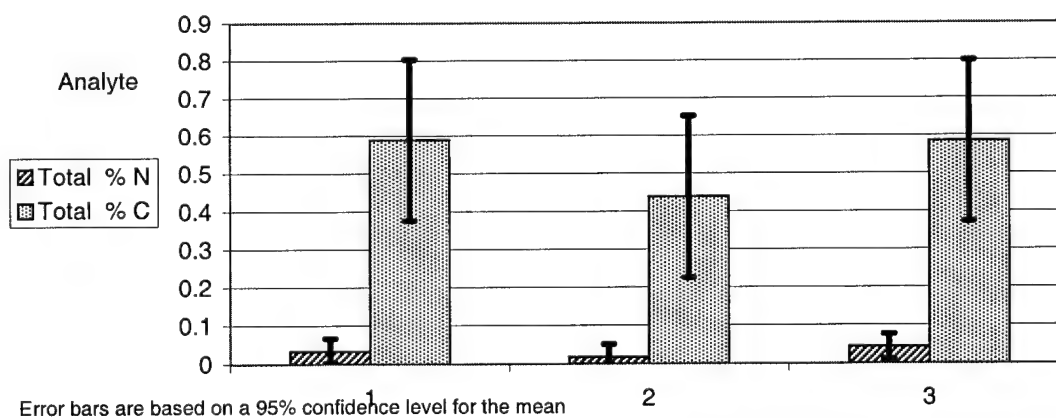
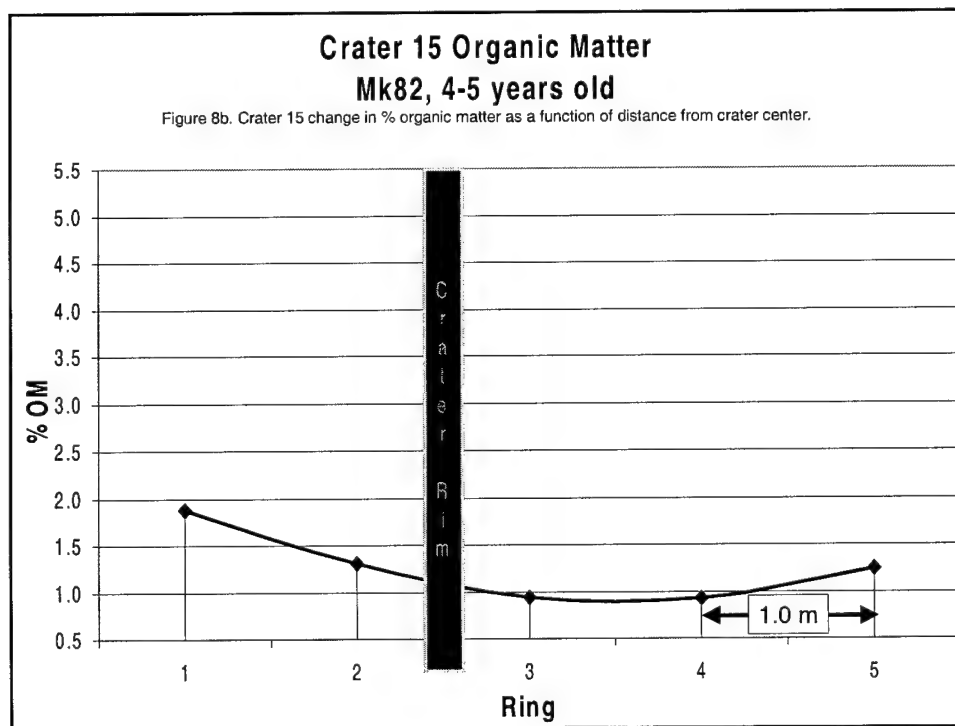
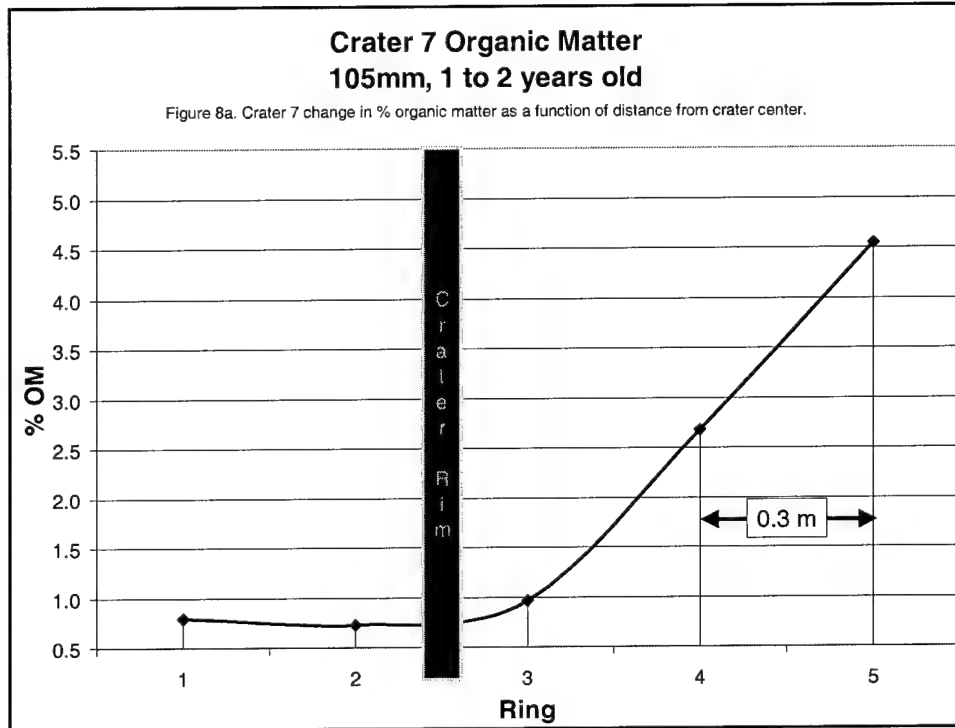
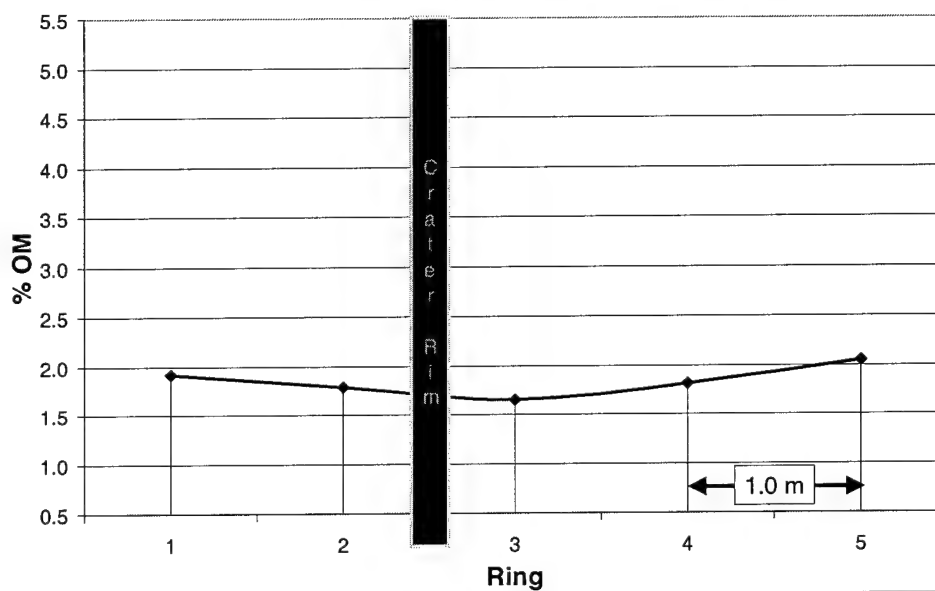


Figure 7f. Crater 15 Ring 4 analysis of replicates.



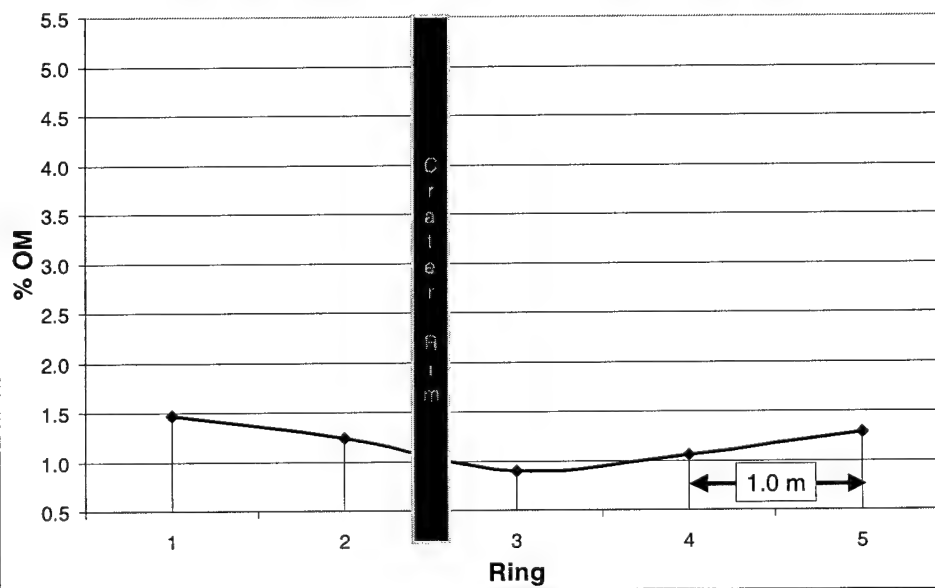
Crater 16 Organic Matter Mk82, 8-9 years old

Figure 8c. Crater 16 change in % organic matter as a function of distance from crater center.



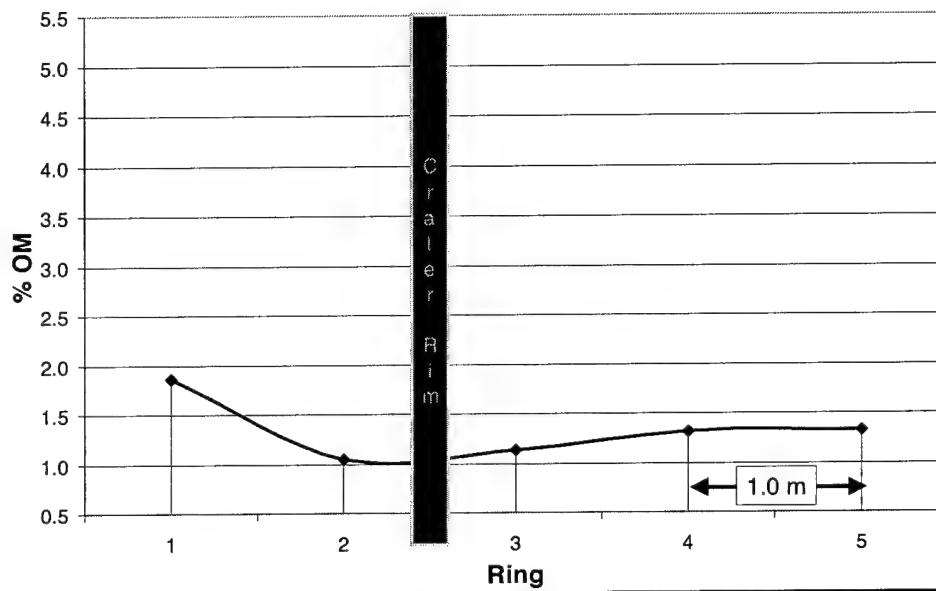
Crater 17 Organic Matter Mk82, 8-9 years old

Figure 8d. Crater 17 change in % organic matter as a function of distance from crater center.



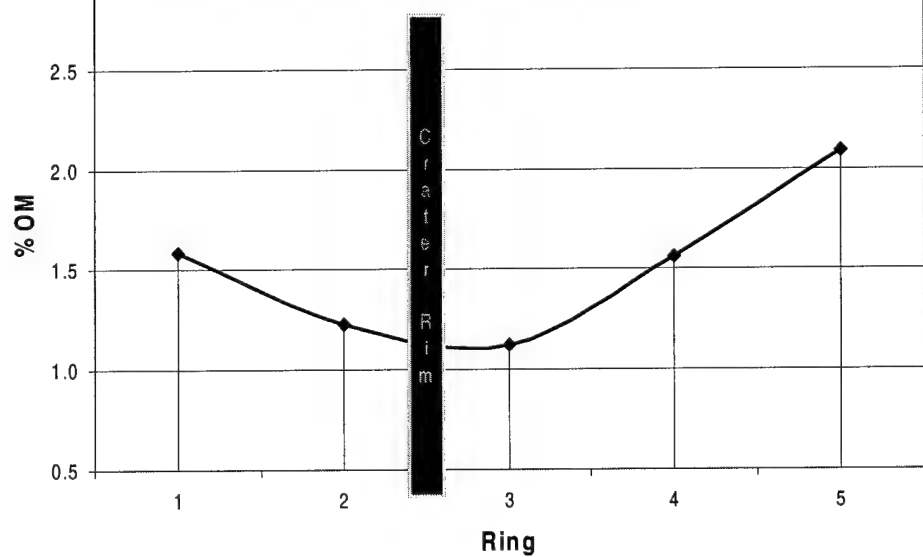
Crater 9 Organic Matter Mk82, 10+ years old

Figure 8e. Crater 9 change in % organic matter as a function of distance from crater center.

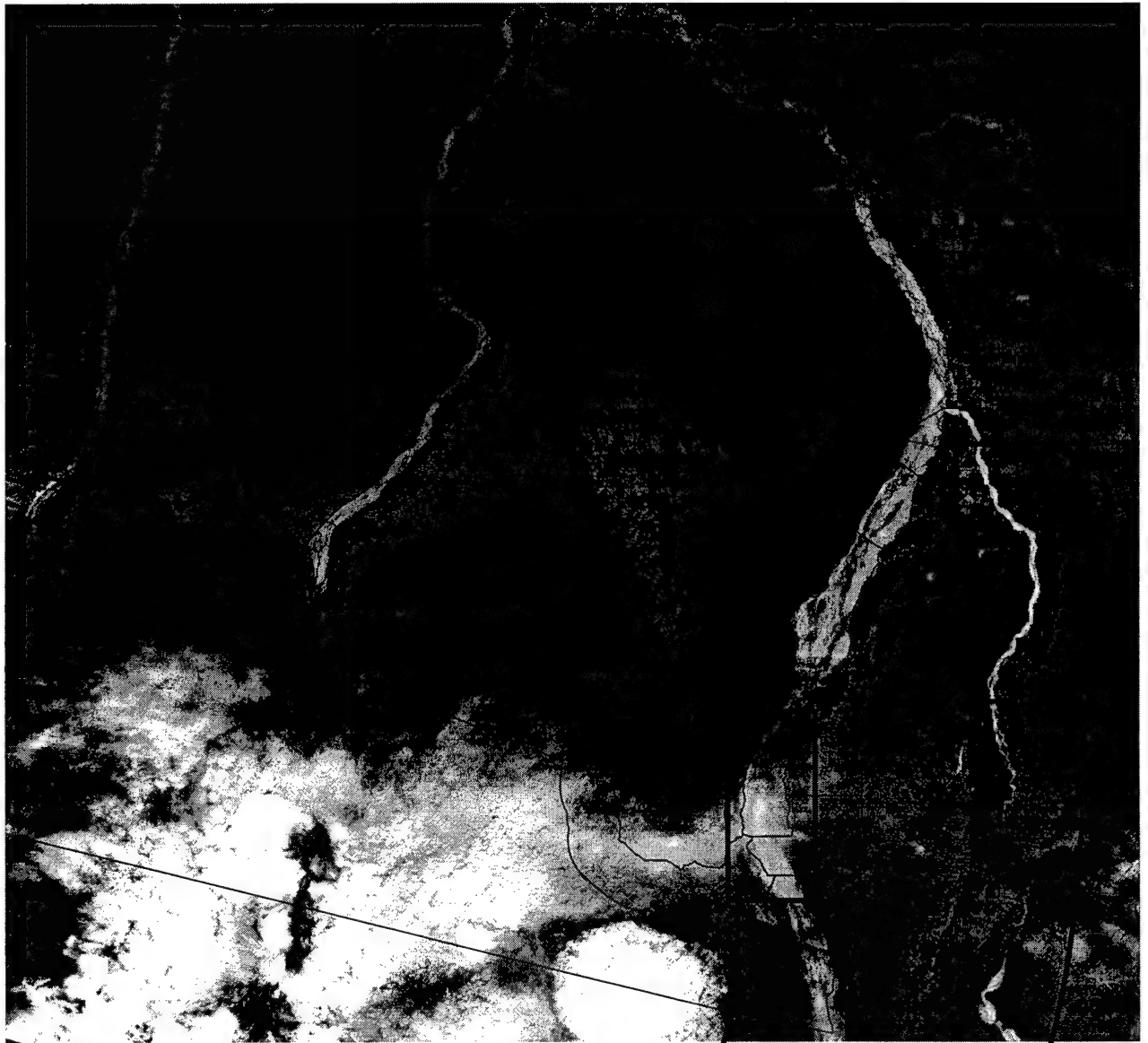


All Craters

Figure 8f. All craters change in % organic matter as a function of distance from crater center.



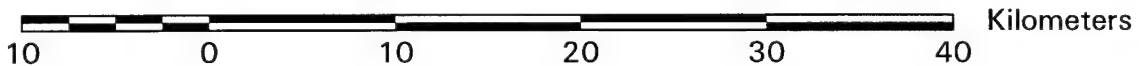
Landsat 7 Enhanced Thematic Mapper Image Color IR, Fort Greely and Vicinity 10 Spetember 1999



Washington Range Control
and Impact Area

Jarvis Creek
Control Area

Scale



Appendix A

US Army Munition	Type	1992 rds	1993 rds	1994 rds	1995 rds	1996 rds	Total rds	Average rounds per year	Crater Radius (m)	Crater Area [+25%SF] (m ²)	Average SA Crater (m ² /yr)	SA of Target Arrays (tgt = 1 ha)	Mass of Filler per round (kg)	*DUD %	*LO %	Average DUD (rds/yr)	Average LO (rds/yr)	Ave. Mass of Filler DUD (kg/yr)	Ave. Mass of Filler LO (kg/yr)
20mm	HE	2500	8904	0	0	0	11752	1959	0.2	0.16	307.51	30	0.01	3.45	0.28	68	5	0.68	0.05
40mm	HE	8	438	7	0	0	489	82	0.4	0.63	51.18	30	0.04	1.32	0.15	1	0	0.04	0.00
60mm	HE	360	898	476	465	622	3025	504	0.6	1.41	712.39	50	0.36	2.48	0	12.50	0.00	4.50	0.00
81mm	HE	420	376	250	346	328	1724	287	1	3.93	1127.78	50	0.953	2.28	0.08	6.55	0.23	6.24	0.22
105mm	HE	2538	1758	1980	2193	663	11080	1847	1.5	8.83	16308.38	50	2.63	4.95	0.09	91.41	1.66	240.41	4.37
120mm	HE	0	120	0	0	0	120	20	1.75	12.02	240.41	50	2.99	3.45	0.28	0.69	0.06	2.06	0.17
84mm	HE	1	41	0	95	6	143	24	1	3.93	93.55	30	0.44	0	0.15	0.00	0.04	0.00	0.02
Frag Grenade	HE	300	230	0	0	0	530	88	0.75	2.21	195.02	20	0.18	3.45	0.28	3.05	0.25	0.55	0.04
2.75 Rkt	HE	205	539	0	0	0	744	124	1	3.93	486.70	50	2.18	8.16	0	10.12	0.00	22.06	0.00
TOW	HEAT	4	3	0	136	69	12	224	37	1	146.53	30	3.1	3.45	0.28	1.29	0.10	3.99	0.32
Hellfire	HEAT	8	5	2	3	0	18	3	1	3.93	11.78	30	2.5	3.45	0.28	0.10	0.01	0.26	0.02
Dragon	HEAT	0	10	0	52	0	62	10	1	3.93	40.56	30	3.93	3.45	0.28	0.36	0.03	0.89	0.07
4.2 in	HE	385	0	0	0	0	385	64	1.75	12.02	771.30	50	3.73	6.92	0.08	4.44	0.05	16.56	0.19
155mm	HE	0	0	0	0	0	16	3	2	15.70	41.87	50	11.5	2.25	0.01	0.06	0.00	0.69	0.00
30mm	HE	520	0	0	0	0	520	87	0.3	0.35	30.62	30	0.025	3.45	0.28	2.99	0.24	0.07	0.01
66mm	HEAT	0	0	0	16	0	16	3	0.6	1.41	3.77	30	0.5	4.52	0.04	0.12	0.00	0.06	0.00
USAF Munition																			
20mm	HE	8302	860	8250	2050	4450	23912	4782	0.2	0.16	750.84	30	0.01	3.45	0.28	164.99	13.39	1.65	0.13
30mm	HE	11950	36000	33300	26960	18020	126230	25246	0.3	0.35	8918.15	30	0.025	3.45	0.28	870.99	70.69	21.77	1.77
2.75 Rkt	HE	976	404	985	221	66	2652	530	1	3.93	2081.82	50	2.18	3.45	0.28	18.30	1.49	39.89	3.24
Maverick	HE	6	0	0	6	7	19	4	5	98.13	372.88	30	36.3	3.45	0.28	0.13	0.01	4.76	0.39
Mk82	HE 500lb	268	215	679	122	193	1477	295	5	98.13	28986.13	75	89	3.45	0.28	10.19	0.83	907.03	73.61
Mk83	HE 1000lb	122	38	53	16	0	229	46	7.5	220.78	10111.78	75	202	3.45	0.28	1.58	0.13	319.18	25.90
Mk84	HE 2000lb	28	173	70	100	20	391	78	10	392.50	30693.50	75	945	3.45	0.28	2.70	0.22	2549.52	206.92

Totals or Averages

* Estimated Rates are italicized

102484.42

975

1271

95

4143

317

AveTotal Filler (kg/yr)

4460

US Army Munition	Source/Remarks
20mm	Jane's, 2000
40mm	Jane's, 2000; USATCES, 2000
60mm	Jane's, 2000; USATCES, 2000
81mm	Jane's, 2000; USATCES, 2000
105mm	Jane's, 2000; USATCES, 2000
120mm	Jane's, 2000
84mm	FAS, USATCES, 2000 Appx B
Frag Grenade	FAS (2001)
2.75 Rkt	FAS (2001)
TOW	FAS (2001)
Hellfire	Hellfire
Dragon	
4.2 in	Jane's, 2000; USATCES, 2000
155mm	Jane's, 2000; USATCES, 2000
30mm	Jane's, 2000
66mm	USATCES, 2000
USAF Munition	
20mm	
30mm	
2.75 Rkt	FAS (2001)
Maverick	FAS (2001)
Mk82	FAS (2001)
Mk83	FAS (2001)
Mk84	FAS (2001)

Fit Greely Installation Area		Acre	Hectare
Total High Hazard Impact Area		662000	267904.78
Surface Area of Target Arrays		85042	34415.647
Average Area Cratered per Year		2409.25153	975
		25.3241793	10.25
% Ft Greely that is High Hazard Impact Area			12.85 %
% High Hazard Impact Area in Use			2.83 %
% Target Array Surface Area Cratered per Year			1.05 %
% High Hazard Impact Area Cratered per Year			0.0298 %
Total Mass of Explosive Filler (DUD + LO)			4460 kg
Theo. Max. Explosive Loading Rate TGT Arrays			0.46 g/m ² /yr
Theo. Max. Explosive Loading Rate Crater Area			43.52 g/m ² /yr

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
100	7.4	0.2	Low	3501	324	4.17	75.7	6.97	456	116	5.7	<0.01	0.16	1.76
101	7.5	0.2	Low	4101	264	3.28	63.2	9.11	458	114	7.1	<0.01	0.17	2.08
102	7.1	0.2	Low	3345	312	4.57	68.2	8.24	416	109	7.3	<0.01	0.17	2.62
103	7.2	0.3	Low	3765	291	3.96	65.9	8.11	444	109	6.5	<0.01	0.17	2.25
104	7.5	0.4	Low	5079	213	3.23	55.2	8.22	453	108	8.0	<0.01	0.17	4.06
105	7.4	0.1	Low	2306	231	4.69	54.1	7.32	369	96.1	6.5	<0.01	0.16	3.45
106	7.5	0.2	Low	4228	311	3.93	69.5	9.00	454	127	6.3	<0.01	0.16	2.01
107	7.6	0.2	Low	4806	201	3.99	57.2	8.34	419	115	9.2	<0.01	0.17	4.71
108	7.7	0.4	Med	5622	157	3.02	33.6	6.30	373	98.3	6.8	<0.01	0.17	4.90
109	7.5	0.1	Low	3265	306	5.47	70.0	8.80	402	122	7.6	<0.01	0.17	3.78
110	7.5	0.3	Low	4121	284	3.40	69.1	8.37	454	123	7.7	<0.01	0.17	2.57
111	7.6	0.2	Low	4095	276	4.04	67.6	7.84	440	120	7.1	<0.01	0.17	2.74
Mean	7.4583333	0.2333333		4019.5	264.19167	3.9785833	62.43	8.0518333	428.2	113.11583	7.1405833		0.1668	3.0763333
Standard Error	0.048396	0.0284268		256.27224	15.131892	0.2026188	3.239305	0.2405902	9.3192534	2.7314846	0.2667709		0.0007799	0.310615
Median	7.5	0.2		4098	279.9	3.9725	66.745	8.23	442.25	114.45	7.082		0.16635	2.6805
Mode	7.5	0.2		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		0.1662	#N/A
Standard Deviation	0.1676486	0.0984732		887.75309	52.418412	0.7018922	11.221282	0.8334289	32.282841	9.4621403	0.9241215		0.0027015	1.0760019
Sample Variance	0.0281061	0.009697		788105.55	2747.6899	0.4926526	125.91716	0.6946038	1042.1818	89.532099	0.8540006		7.298E-06	1.1577801
Kurtosis	0.9925822	-0.309375		0.3981904	-0.216623	0.3842792	3.3722423	0.3365783	-0.454964	-0.390992	1.2222043		0.5792019	-1.057362
Skewness	-1.006791	0.5585276		-0.018879	-0.853558	0.6460258	-1.651802	-0.843708	-0.9478	-0.507211	0.7666829		0.2581511	0.5628269
Range	0.6	0.3		3316	167.3	2.445	42.19	2.804	88.2	30.7	3.521		0.0102	3.143
Minimum	7.1	0.1		2306	156.9	3.023	33.55	6.304	369.4	96.1	5.687		0.162	1.759
Maximum	7.7	0.4		5622	324.2	5.468	75.74	9.108	457.6	126.8	9.208		0.1722	4.902
Sum	89.5	2.8		48234	3170.3	47.743	749.16	96.622	5138.4	1357.39	85.687		2.0016	36.916
Count	12	12		12	12	12	12	12	12	12	12		12	12
Conf Level(95.0%)	0.1065189	0.0625669		564.05169	33.305087	0.4459612	7.1296659	0.5295357	20.511549	6.0119602	0.5871591		0.0017165	0.6836593

* Mehlich 3 Extract

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH ₄ -N (mg/kg)	NO ₃ -N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
100	19.5	46	50	4	Silt Loam/Sandy Loam	4.4	15.2	0.169	2.891	5.0	7.5	Scrub Wash Cntl
101	9.4	45	51	4	Silt Loam	4.1	9.0	0.133	1.904	3.3	7.5	Scrub Wash Cntl
102	10.6	51	45	4	Sandy Loam	2.3	32.7	0.131	1.935	3.3	7.5	Scrub Wash Cntl
103	10.9	48	48	4	Sandy Loam	1.5	38.0	0.125	1.959	3.4	7.5	Scrub Wash Cntl
104	5.8	60	37	3	Sandy Loam	2.1	36.9	0.064	1.018	1.8	7.5	Scrub Wash Cntl
105	10.4	50	47	3	Sandy Loam	5.5	5.7	0.151	2.161	3.7	7.5	Scrub Wash Cntl
106	9.5	44	52	4	Silt Loam	3.5	6.8	0.125	1.581	2.7	7.5	Scrub Wash Cntl
107	6.8	56	40	4	Sandy Loam	1.9	26.5	0.100	1.217	2.1	7.5	Scrub Wash Cntl
108	2.2	80	17	3	Loamy Sand	1.2	5.3	0.018	0.411	0.7	7.5	Scrub Wash Cntl
109	9.9	57	39	4	Sandy Loam	7.6	3.9	0.207	2.775	4.8	7.5	Scrub Wash Cntl
110	5.8	54	41	5	Sandy Loam	1.5	35.3	0.086	1.217	2.1	7.5	Scrub Wash Cntl
111	9.2	46	50	4	Silt Loam/Sandy Loam	6.7	3.9	0.123	1.799	3.1	7.5	Scrub Wash Cntl
Mean	9.166667	53.083333	43.083333	3.833333		NH ₄ -N	NO ₃ -N	N	C	OM	Buffer pH	
Standard Error	1.2024806	2.8668913	2.7919211	0.1666667		3.525	18.266667	0.1193333	1.739	2.998036	7.5	
Median	9.45	50.5	46	4		0.6243936	4.1455221	0.0141343	0.2050403	0.3534895	0	
Mode	5.8	46	50	4		2.9	12.1	0.125	1.8515	3.191986	7.5	
Standard Deviation	4.165515	9.9312027	9.6714983	0.5773503		1.5	3.9	0.125	1.217	2.098108	7.5	
Sample Variance	17.351515	98.628788	93.537879	0.3333333		2.162963	14.36051	0.0489626	0.7102805	1.2245236	0	
Kurtosis	3.326008	4.7852097	4.6165143	0.6545455		4.6784091	206.22424	0.0023973	0.5044984	1.4994579	0	
Skewness	1.0356152	1.9779723	-1.9322345	-0.062984		-0.653418	-1.930578	0.9677271	-0.022078	-0.022078	#DIV/0!	
Range	17.3	36	35	2		0.7550609	0.3769507	-0.391862	-0.081123	-0.081123	#DIV/0!	
Minimum	2.2	44	17	3		6.4	34.1	0.189	2.48	4.27552	0	
Maximum	19.5	80	52	5		1.2	3.9	0.018	0.411	0.708564	7.5	
Sum	110	637	517	46		7.6	38	0.207	2.891	4.984084	7.5	
Count	12	12	12	12		42.3	219.2	1.432	20.868	35.976432	90	
Conf Level(95.0%)	2.6456433	6.3099884	6.1449799	0.366831		12	12	12	12	12	12	
						1.3742818	9.1242373	0.0311093	0.4512909	0.7780255	0	

* Mehlich 3 Extract

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
300	7.3	0.1	Low	2086	330	3.35	42.4	5.63	359	144	5.3	<0.01	0.18	5.55
301	7.1	0.1	Low	1985	333	3.20	36.8	5.45	365	132	5.2	<0.01	0.17	5.27
302	7.3	0.2	Low	2224	350	3.87	49.4	6.28	350	151	4.8	<0.01	0.17	5.76
1243	7.0	0.2	Low	1552	290	5.07	39.7	3.77	312	105	2.9	<0.01	0.20	3.14
1274	6.9	0.1	Low	1278	196	5.28	38.1	4.11	262	105	5.0	<0.01	0.21	4.24
1439	5.3	0.1	Low	5969	802	2.83	108	14.8	457	148	3.5	<0.01	0.17	1.07
1722	4.7	0.1	Low	1243	254	3.18	67.8	1.82	430	22.2	1.8	<0.01	0.21	0.99
1913	5.2	0.1	Low	4323	560	3.16	105	29.4	452	110	2.2	<0.01	0.17	1.08
1298A	5.3	0.1	Low	2202	416	4.82	186	1.94	459	50.3	1.5	<0.01	0.20	1.07
1741A	5.1	0.1	Low	2878	391	9.23	179	19.1	395	69.1	2.0	<0.01	0.37	1.07
1752A	6.6	0.1	Low	7976	773	3.39	72.9	5.29	374	72.1	3.9	0.01	0.18	1.69
1762A	6.7	0.1	Low	11830	1052	7.72	121	16.8	343	235	1.6	0.10	0.17	1.20
Mean	6.2083333	0.1166667		3795.5	478.85	4.5904167	87.120833	9.53325	379.725	111.96667	3.3271667		0.1994	2.6768917
Standard Error	0.2866891	0.0112367		941.34593	76.053761	0.5813536	15.37449	2.4735534	17.777672	16.244676	0.4332393		0.0158866	0.5736009
Median	6.65	0.1		2213	370.25	3.6315	70.37	5.538	369.45	107.55	3.2065		0.18075	1.444
Mode	7.3	0.1		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	1.065
Standard Deviation	0.9931203	0.0389249		3260.918	263.45796	2.0138681	53.258796	8.5686405	61.583663	56.273209	1.5007849		0.0550329	1.987012
Sample Variance	0.9862879	0.0015152		10633586	69410.095	4.0566646	2836.4993	73.4216	3792.5475	3166.6741	2.2523554		0.0030286	3.9482166
Kurtosis	-1.865962	2.64		2.4264805	0.4724323	1.5639292	-0.307968	1.1706254	-0.4528	1.0244355	-1.828968		9.3448532	-1.511485
Skewness	-0.334148	2.0552372		1.6945389	1.1785784	1.5062701	0.9226058	1.3487921	-0.270015	0.5644141	0.1636965		2.9368805	0.6767194
Range	2.6	0.1		10587	856	6.398	148.99	27.597	197.2	213.1	3.764		0.2003	4.7673
Minimum	4.7	0.1		1243	196	2.829	36.81	1.823	261.8	22.2	1.509		0.1659	0.9907
Maximum	7.3	0.2		11830	1052	9.227	185.8	29.42	459	235.3	5.273		0.3662	5.758
Sum	74.5	1.4		45546	5746.2	55.085	1045.45	114.399	4556.7	1343.6	39.926		2.3928	32.1227
Count	12	12		12	12	12	12	12	12	12	12		12	12
Conf Level(95.0%)	0.6309988	0.0247317		2071.8895	167.39328	1.2795514	33.839042	5.4442572	39.128412	35.754309	0.9535537		0.0349662	1.2624878

* Mehlich 3 Extract

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH ₄ -N (mg/kg)	NO ₃ -N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
300	6.0	68	28	4	Sandy Loam	5.6	2.0	0.102	1.167	2.0	7.5	Scrub
301	6.7	74	23	3	Loamy Sand	4.3	6.0	0.097	1.523	2.6	7.5	Scrub
302	7.9	65	31	4	Sandy Loam	6.2	24.2	0.122	1.582	2.7	7.5	Scrub
1243	8.9	80	15	5	Loamy Sand	3.8	9.2	0.085	1.131	1.9	7.4	Scrub
1274	9.7	84	12	4	Loamy Sand	5.3	2.2	0.122	2.354	4.1	7.4	Scrub
1439	64.8	44	38	18	Loam	13.2	2.5	1.007	10.94	18.9	7.0	Scrub
1722	31.1	40	49	11	Loam	3.4	2.7	0.258	5.121	8.8	6.8	Scrub
1913	22.0	42	34	24	Loam	3.6	7.7	0.719	10.40	17.9	7.1	Scrub
1298A	39.6	36	56	8	Silt Loam	11.8	1.4	0.364	7.616	13.1	6.8	Scrub
1741A	25.3	34	42	24	Loam	18.2	1.8	0.424	8.056	13.9	7.0	Scrub
1752A	26.9	46	40	14	Loam	1.8	9.6	0.535	8.968	15.5	7.4	Scrub
1762A	76.0	48	36	16	Loam	2.4	23.3	0.861	13.49	23.3	7.4	Scrub
Mean	27.075	55.083333	33.666667	11.25		NH ₄ -N	NO ₃ -N	N	C	OM	Buffer pH	
Standard Error	6.6731271	5.1807603	3.7321968	2.2634279		6.6333333	7.7166667	0.3913333	6.029	10.393996	7.2333333	
Median	23.65	47	35	9.5		1.4591578	2.3251534	0.093602	1.2797801	2.2063408	0.0791368	
Mode	#N/A	#N/A	#N/A	4		4.8	4.35	0.311	6.3685	10.979294	7.4	
Standard Deviation	23.11639	17.94668	12.928709	7.8407444		#N/A	#N/A	0.122	#N/A	#N/A	7.4	
Sample Variance	534.3675	322.08333	167.15152	61.477273		5.0546708	8.0545677	0.3242469	4.4332882	7.6429888	0.2741378	
Kurtosis	0.6493314	-1.472528	-0.273297	-1.112603		25.549697	64.876061	0.1051361	19.654044	58.415278	0.0751515	
Skewness	1.2061386	0.4735045	-0.122107	0.587886		1.1880316	1.1708007	-0.634104	-1.478037	-1.478037	-1.382154	
Range	70	50	44	21		1.4183321	1.5001116	0.8167118	0.2413147	0.2413147	-0.609536	
Minimum	6	34	12	3		16.4	22.8	0.922	12.359	21.306916	0.7	
Maximum	76	84	56	24		1.8	1.4	0.085	1.131	1.949844	6.8	
Sum	324.9	661	404	135		18.2	24.2	1.007	13.49	23.25676	7.5	
Count	12	12	12	12		79.6	92.6	4.696	72.348	124.72795	86.8	
Conf Level(95.0%)	14.687461	11.402782	8.2145139	4.9817738		12	12	12	12	12	12	
						3.2115862	5.1176307	0.2060168	2.8167783	4.8561259	0.1741789	

* Mehlich 3 Extract

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
158	6.7	0.1	Low	3628	570	3.46	148	15.4	435	139	3.0	<0.01	0.16	1.47
501	7.5	0.2	Low	6130	533	4.81	105	18.3	404	116	3.0	<0.01	0.17	2.17
502	5.9	0.1	Low	4906	689	4.74	155	12.4	429	133	2.1	<0.01	0.16	1.32
1001	5.8	0.1	Low	6575	830	13.7	176	24.4	450	144	3.2	<0.01	0.17	1.30
1019	4.9	0.1	Low	2348	378	10.2	128	6.04	432	110	2.4	<0.01	0.17	1.16
1124	5.3	0.1	Low	4289	779	5.35	145	16.1	444	120	2.3	<0.01	0.17	1.20
1153	4.6	0.1	Low	1789	371	25.8	125	3.20	448	174	2.0	<0.01	0.18	1.29
1191	6.0	0.1	Low	4407	696	4.66	75.2	11.7	483	109	2.8	<0.01	0.16	1.44
1316	6.9	0.2	Low	5347	587	4.28	71.5	9.24	425	142	2.0	<0.01	0.17	1.41
1981	6.5	0.1	Low	4517	592	3.84	121	8.67	437	134	2.1	<0.01	0.16	1.46
1326A	5.4	0.1	Low	4261	649	7.82	157	12.1	405	157	2.1	<0.01	0.16	1.61
478A	6.3	0.1	Low	3599	575	4.31	148	24.7	408	141	3.3	<0.01	0.17	2.30
Mean	5.9833333	0.1166667		4316.3333	603.96667	7.7465833	129.50833	13.53375	433.175	134.86667	2.5200833		0.1668	1.511
Standard Error	0.2455153	0.0112367		399.84238	40.126666	1.8627802	9.3564424	1.9220731	6.4828576	5.6085343	0.1418285		0.0015514	0.1038053
Median	5.95	0.1		4348	589.45	4.771	136.45	12.27	433.4	136.55	2.3515		0.1659	1.4265
Mode	#N/A	0.1		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		0.1698	#N/A
Standard Deviation	0.8504901	0.0389249		1385.0946	139.00285	6.45286	32.411667	6.6582566	22.457278	19.428533	0.4913082		0.0053742	0.3595922
Sample Variance	0.7233333	0.0015152		1918487.2	19321.792	41.639402	1050.5162	44.332381	504.32932	377.46788	0.2413837		2.888E-05	0.1293065
Kurtosis	-0.5046	2.64		0.0080033	-0.115558	5.8436367	-0.242467	-0.373754	1.1185127	0.0937372	-1.740675		2.3695039	1.5952187
Skewness	0.0627549	2.0552372		-0.23266	-0.255378	2.3532513	-0.688618	0.401785	0.6766499	0.436405	0.3766529		1.3176884	1.5709874
Range	2.9	0.1		4786	459.1	22.339	104.92	21.52	79.5	65.8	1.293		0.0198	1.136
Minimum	4.6	0.1		1789	371	3.461	71.48	3.2	403.9	108.5	1.96		0.1602	1.162
Maximum	7.5	0.2		6575	830.1	25.8	176.4	24.72	483.4	174.3	3.253		0.18	2.298
Sum	71.8	1.4		51796	7247.6	92.959	1554.1	162.405	5198.1	1618.4	30.241		2.0016	18.132
Count	12	12		12	12	12	12	12	12	12	12		12	12
Conf Level(95.0%)	0.5403759	0.0247317		880.04759	88.31824	4.0999537	20.593401	4.2304565	14.268681	12.344307	0.3121625		0.0034146	0.2284741

* Mehlich 3 Extract

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH ₄ -N (mg/kg)	NO ₃ -N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
158	22.1	16	74	10	Silt Loam	15.8	2.2	0.363	5.033	8.7	7.4	Broadleaf
501	27.1	52	44	4	Sandy Loam	2.1	10.8	0.289	4.445	7.7	7.5	Broadleaf
502	34.8	36	52	12	Silt Loam	4.6	16.4	0.349	5.761	9.9	7.3	Broadleaf
1001	56.3	44	48	8	Loam	39.4	3.8	0.536	10.01	17.3	7.3	Broadleaf
1019	40.5	46	44	10	Loam	2.2	1.9	0.427	8.593	14.8	6.7	Broadleaf
1124	44.6	52	40	8	Loam/Sandy Loam	15.1	6.6	0.414	8.812	15.2	7.1	Broadleaf
1153	34.6	36	54	10	Silt Loam	19.7	1.5	0.315	6.484	11.2	7.0	Broadleaf
1191	31.3	58	30	12	Sandy Loam	2.9	3.1	0.295	5.923	10.2	7.3	Broadleaf
1316	26.5	45	51	4	Silty Loam	2.1	24.4	0.272	4.316	7.4	7.4	Broadleaf
1981	5.6	36	54	10	Silt Loam	12.4	10.5	0.263	4.36	7.5	7.5	Broadleaf
1326A	30.7	26	48	26	Loam	9.4	1.8	0.407	8.512	14.7	7.2	Broadleaf
478A	26.2	16	66	18	Silt Loam	3.6	1.7	0.351	5.829	10.0	7.4	Broadleaf
Mean	CEC	Sand	Silt	Clay		NH ₄ -N	NO ₃ -N	N	C	OM	Buffer pH	
Standard Error	31.691667	38.583333	50.416667	11		10.775	7.0583333	0.35675	6.50625	11.216775	7.2583333	
Median	3.6097607	3.9513295	3.3108141	1.7320508		3.1661114	2.0922099	0.0228828	0.5718175	0.9858134	0.0668086	
Mode	31	40	49.5	10		7	3.45	0.35	5.876	10.130224	7.3	
Standard Deviation	#N/A	36	44	10		2.1	#N/A	#N/A	#N/A	#N/A	7.4	
Sample Variance	12.504578	13.687807	11.468996	6		10.967732	7.2476276	0.0792684	1.9808339	3.4149577	0.2314316	
Kurtosis	156.36447	187.35606	131.53788	36		120.29114	52.528106	0.0062835	3.9237031	11.661936	0.0535606	
Skewness	1.6037496	-0.630905	1.0451021	3.0181818		3.6268939	1.8237356	0.9209238	-1.148368	-1.148368	2.025967	
Range	-0.070156	-0.514636	0.4916866	1.5030303		1.7650442	1.5198579	0.9567559	0.5490063	0.5490063	-1.394799	
Minimum	50.7	42	44	22		37.3	22.9	0.273	5.694	9.816456	0.8	
Maximum	5.6	16	30	4		2.1	1.5	0.263	4.316	7.440784	6.7	
Sum	56.3	58	74	26		39.4	24.4	0.536	10.01	17.25724	7.5	
Count	380.3	463	605	132		129.3	84.7	4.281	78.075	134.6013	87.1	
Conf Level(95.0%)	12	12	12	12		12	12	12	12	12	12	
	7.9450338	8.6968221	7.2870564	3.8122201		6.9685677	4.6049252	0.0503648	1.2585625	2.1697617	0.1470447	

* Mehlich 3 Extract

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
124	5.4	0.2	Low	2812	551	4.45	91.1	7.21	545	122	1.8	<0.01	0.17	1.08
711	4.5	0.1	Low	3064	407	6.14	168	29.3	413	238	10.0	1.02	0.19	1.10
794	6.5	0.1	Low	6368	712	4.98	104	15.3	466	144	1.9	<0.01	0.16	1.49
1000	5.4	0.2	Low	6845	1113	15.5	489	17.4	466	180	2.0	0.03	0.17	1.48
1020	5.7	0.1	Low	2561	408	3.12	81.3	8.79	441	122	5.7	<0.01	0.17	1.80
1287	6.4	0.1	Low	2635	429	3.06	68.6	7.79	448	121	5.8	<0.01	0.16	1.79
1321	7.1	0.2	Low	4835	645	9.24	282	19.6	410	140	2.8	<0.01	0.16	2.51
1328	4.7	0.2	Low	2425	494	24.5	215	4.42	451	266	2.6	<0.01	0.18	0.99
1331	5.4	0.1	Low	2852	656	3.13	130	6.22	509	124	5.0	<0.01	0.17	1.61
1362	5.7	0.1	Low	2832	566	3.16	89.1	4.33	479	113	2.1	<0.01	0.17	1.41
1412	5.8	0.1	Low	4462	898	3.37	128	6.47	462	120	3.8	<0.01	0.16	1.49
1842	5.2	0.1	Low	2615	515	3.24	150	4.72	463	98.5	1.8	<0.01	0.16	1.34
Mean	5.65	0.133333	EC	Ca	Mg	P	K	Zn	Fe	Mn	Cu		Cr	Pb
Standard Error	0.2137331	0.0142134		3692.1667	616.13333	6.9966667	166.25667	10.961417	462.66667	149.07083	3.7723333		0.167575	1.5076417
Median	5.55	0.1		450.39836	61.050304	1.9154857	34.312494	2.2502184	10.749851	15.144807	0.7172633		0.002172	0.1181396
Mode	5.4	0.1		2842	558.85	3.9105	128.75	7.497	462.3	122.9	2.717		0.165	1.483
Standard Deviation	0.740393	0.0492366		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A		0.165	#N/A
Sample Variance	0.5481818	0.0024242		1560.2257	211.48446	6.6354372	118.86197	7.794985	37.238576	52.463149	2.484673		0.0075239	0.4092475
Kurtosis	0.0964564	-1.65		2434304.2	44725.675	44.029027	14128.167	60.761792	1386.7115	2752.382	6.1736001		5.661E-05	0.1674835
Skewness	0.4225267	0.8124038		0.2411383	1.6951548	4.2078158	4.8710161	1.3968845	1.229654	1.4309311	2.6638526		3.0117935	2.4912666
Range	2.6	0.1		1.274594	1.3615106	2.118121	2.1134475	1.3937155	0.7892639	1.5578546	1.6090808		1.8531782	1.2227147
Minimum	4.5	0.1		4420	705.6	21.478	420.53	24.973	134.4	167.75	8.222		0.0261	1.5203
Maximum	7.1	0.2		2425	407.4	3.062	68.57	4.327	410.4	98.45	1.798		0.1602	0.9907
Sum	67.8	1.6		6845	1113	24.54	489.1	29.3	544.8	266.2	10.02		0.1863	2.511
Count	12	12		44306	7393.6	83.96	1995.08	131.537	5552	1788.85	45.268		2.0109	18.0917
Conf Level(95.0%)	0.4704235	0.0312835		991.3206	134.37088	4.2159578	75.521329	4.9526997	23.660274	33.333512	1.5786867		0.0047805	0.2600236

* Mehlich 3 Extract

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH ₄ -N (mg/kg)	NO ₃ -N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
124	26.1	54	42	4	Sandy Loam	4.3	2.2	0.177	3.237	5.6	7.3	Mixed
711	53.3	54	32	14	Sandy Loam	11.6	2.3	0.587	11.08	19.1	7.3	Mixed
794	41.7	44	48	8	Loam	10.5	2.6	0.330	15.88	11.4	7.4	Mixed
1000	70.1	52	38	10	Loam/Sandy Loam	25.8	2.0	0.581	14.47	24.9	7.2	Mixed
1020	23.0	36	52	12	Silt Loam	2.4	1.3	0.195	3.848	6.6	7.4	Mixed
1287	16.5	42	50	8	Silt Loam/Loam	2.6	1.7	0.159	3.177	5.5	7.4	Mixed
1321	27.5	58	36	6	Sandy Loam	21.2	4.5	0.352	6.966	12.0	7.4	Mixed
1328	38.3	30	60	10	Silt Loam	7.2	1.4	0.403	9.583	16.5	7.0	Mixed
1331	28.9	38	51	11	Silt Loam	12.5	1.3	0.261	6.172	10.6	7.3	Mixed
1362	26.1	53	39	8	Sandy Loam	6.6	10.1	0.221	4.575	7.9	7.3	Mixed
1412	43.9	44	44	12	Loam	8.6	3.7	0.272	6.692	11.5	7.3	Mixed
1842	12.2	42	50	8	Silt Loam/Loam	4.2	18.5	0.179	3.461	6.0	7.3	Mixed
Mean	33.966667	45.583333	45.166667	9.25		NH ₄ -N	NO ₃ -N	N	C	OM	Buffer pH	
Standard Error	4.7250514	2.4846753	2.3252023	0.8083372		9.7916667	4.3	0.30975	6.6540833	11.47164	7.3	
Median	28.2	44	46	9		2.1027204	1.4705184	0.0429609	1.0141065	1.7483196	0.0325669	
Mode	26.1	54	50	8		7.9	2.25	0.2665	6.38	10.99912	7.3	
Standard Deviation	16.368058	8.6071676	8.054737	2.8001623		#N/A	1.3	#N/A	#N/A	#N/A	7.3	
Sample Variance	267.91333	74.083333	64.878788	7.8409091		7.2840371	5.094025	0.1488209	3.512968	6.0563568	0.1128152	
Kurtosis	0.7966129	-0.887106	-0.506621	-0.151639		53.057197	25.949091	0.0221477	12.340944	36.679458	0.0127273	
Skewness	0.9351747	-0.243193	0.0712083	-0.158376		1.02544633	5.8282501	0.0668421	0.7843352	0.7843352	4.3326531	
Range	57.9	28	28	10		1.2548407	2.4163481	1.0519604	1.1163127	1.1163127	-1.823462	
Minimum	12.2	30	32	4		23.4	17.2	0.428	11.293	19.469132	0.4	
Maximum	70.1	58	60	14		2.4	1.3	0.159	3.177	5.477148	7	
Sum	407.6	547	542	111		25.8	18.5	0.587	14.47	24.94628	7.4	
Count	12	12	12	12		117.5	51.6	3.717	79.849	137.65968	87.6	
Conf Level(95.0%)	10.399773	5.4687361	5.1177383	1.7791392		12	12	12	12	12	12	
						4.6280587	3.2365907	0.0945563	2.2320345	3.8480275	0.0716794	

* Mehlich 3 Extract

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
E05	7.2	0.2	Low	3625	366	4.76	73.9	8.84	341	127	5.7	<0.01	0.18	3.27
E07	7.6	0.1	Low	5063	188	3.17	43.8	15.0	325	120	7.8	<0.01	0.18	3.99
G01	6.6	0.3	Low	4321	436	7.82	118	15.2	368	112	5.0	<0.01	0.17	2.51
I01	6.9	0.6	Low	2051	210	5.97	90.5	8.97	202	41.3	2.7	0.05	0.09	0.89
I04	7.4	0.5	Low	2132	125	0.19	66.4	8.03	211	52.6	4.2	0.08	0.06	1.17
I06	7.4	0.3	Low	3589	204	1.91	87.4	4.26	359	77.7	3.9	<0.01	0.12	1.01
J03	7.2	0.3	Low	2897	270	1.79	115	5.29	324	61.7	3.5	<0.01	0.17	0.28
J06	7.4	0.4	Low	3116	140	1.39	87.8	7.68	246	56.7	4.2	<0.01	0.07	0.79
K03	7.2	0.2	Low	2894	234	6.30	97.6	5.53	281	66.4	3.6	<0.01	0.08	0.12
K04	7.7	0.2	Low	1937	139	5.45	51.2	6.44	320	61.8	7.5	<0.01	0.13	2.45
K05	7.6	0.4	Low	3037	131	1.15	59.5	11.3	307	64.9	3.5	<0.01	0.08	0.81
L04	7.3	0.3	Low	2062	116	0.70	55.7	7.26	230	49.7	3.3	0.02	0.03	0.67
Q01	7.4	0.4	Low	2165	187	4.01	94.6	6.42	222	54.0	4.9	0.03	0.08	0.65
Q02	7.1	0.4	Low	2382	224	5.21	112	7.60	210	52.5	4.3	0.03	0.06	1.05
Craters 17	7.49333333	0.27333333		3023.0667	140.68467	5.8980667	36.4333333	8.4605333	417.44667	79.055333	4.3997333		1.1137	7.4038667
16	7.28	0.35333333		3066.2	190.35333	2.5162733	74.082667	6.5988	318.41333	66.732667	3.6160667		0.1470933	0.8760333
15	7.76	0.1866667		2372.7333	135.626	4.2341467	54.374	8.3809333	309.48	57.448	4.9007333		0.26432	0.9778467
9	7.7	0.2		2572.1	187.4	10.0	40.0	15.2	567.9	175.2	6.7		1.0	8.2
7	7.53333333	0.12		1748.7467	142.77067	7.8664667	29.915267	6.7811333	345.51333	79.484	3.1483333		0.7188933	5.507
2	7.3666667	0.2466667		3246.2	197.56	10.5386	55.263333	5.8754667	418.32667	79.526	3.6602667		0.8535467	5.8414667

CRREL

E05	7.71	0.31		1741.8112	134.30446	7.8875847	102.35121	9.6665823			5.4512374	0.0830252	0.0652535	1.9153149
E07	7.75	0.44		1507.0548	74.550553	2.4726483	35.964874	3.8526512			3.6692044	0.05627	0.1028698	1.851749
G01	6.61	0.58		2614.6758	277.82576	20.907724	127.15536	12.702292			5.6487108	0.1	0.08	2.3
I01	7.66	0.29		1288.6933	108.5977	6.979073	59.398413	4.334114			4.6445571	0.0793823	0.1282325	9.0862739
I04	8.03	0.27		1009.3956	68.966212	3.1361161	32.077571	4.2632233			6.0114941	0.080863	0.1427815	2.1207533
I06	7.64	0.46		1684.9828	83.405447	7.9302136	61.126037	4.9803595			5.4685705	0.1444431	0.1218694	2.4865911
J03	8.05	0.25		1656	172	2	112	4.9			8.5	0.0773444	0.2044152	1.8651953
J06	7.85	0.62		1484.2635	72.724307	2.152078	32.474578	4.0989341			4.543765	0.0543228	0.0997657	1.7221192
K03	7.55	0.27		1100.068	98.653961	7.5075306	39.841682	4.3516903			4.6725443	0.0712774	0.1125911	1.7272386
K04	7.74	0.29		1728.1734	115.5101	7.3145841	43.072525	5.1916699			5.2031114	0.0796609	0.1565885	2.4338197
K05	7.86	0.35		1715.699	81.622984	3.7220768	38.865432	4.8530387			4.3700518	0.0631735	0.1087159	1.8511536
L04	7.79	0.31		1407.1928	91.456599	3.8722379	32.694949	4.4254676			4.4889352	0.0600818	0.115759	1.7038777

CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH4-N (mg/kg)	NO3-N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
9.8	60	36	4	Sandy Loam	1.3	25.1	0.158	1.951	3.4	7.5	Scrub Wash Impact Area
4.9	62	34	4	Sandy Loam	2.7	3.8	0.925	0.061	0.1	7.5	Scrub Wash Impact Area
21.1	50	46	4	Sandy Loam	1.5	47.9	0.362	5.047	8.7	7.5	Scrub Wash Impact Area
15.4	66	32	2	Sandy Loam	2.7	110	0.229	2.897	5.0	7.5	Scrub Wash Impact Area
5.5	74	22	4	Loamy Sand/Sandy Loam	2.2	61.4	0.110	1.425	2.5	7.5	Scrub Wash Impact Area
8.2	48	46	6	Sandy Loam	2.5	47.6	0.099	1.329	2.3	7.5	Scrub Wash Impact Area
47.9	64	30	6	Sandy Loam	1.7	55.5	0.179	2.569	4.4	7.5	Scrub Wash Impact Area
8.2	62	34	4	Sandy Loam	1.5	43.0	0.061	0.823	1.4	7.4	Scrub Wash Impact Area
17.6	58	38	4	Sandy Loam	4.4	3.2	0.174	2.411	4.2	7.2	Scrub Wash Impact Area
8.6	66	30	4	Sandy Loam	6.8	1.7	0.082	1.339	2.3	7.4	Scrub Wash Impact Area
8.8	62	34	4	Sandy Loam	6.2	2.9	0.053	0.950	1.6	7.5	Scrub Wash Impact Area
8.6	68	28	4	Sandy Loam	2.3	60.1	0.065	0.914	1.6	7.3	Scrub Wash Impact Area
15.3	66	30	4	Sandy Loam	6.0	33.2	0.196	2.606	4.5	7.5	Scrub Wash Impact Area
16.7	60	38	2	Sandy Loam	4.4	67.9	0.220	3.277	5.6	7.4	Scrub Wash Impact Area
8.1266667	71.733333	23.6	4.666667		2.8	9.6733333	0.0431333	0.6936	1.1957664	7.5	
11.246667	66.266667	27.6	6.1333333		3.68	25.793333	0.0719333	1.0710667	1.8465189	7.4733333	
5.68	72.266667	23.2	4.5333333		3.62	9.7	0.0448	0.7323333	1.2625427	7.4466667	
8.2	61.5	30.1	8.4		1.9	25.1	0.1	0.8	1.3	7.5	
11.26	72.133333	21.733333	6.1333333		2.0533333333	3.8666667	0.0769333	1.1274667	1.9437525	7.5	
20.086667	45.733333	47.866667	6.4		3.92	17.246667	0.1515333	2.2183333	3.8244067	7.5	

4.89464	86	12.4	1.6		<1	27		1.28	2.20672		
1.76528	84	12.4	3.6		<1	7		0.53	0.91372		
17.49232	83.2	15.2	1.6		2	81		1.79	3.08596		
4.97	75.2	22	2.8		2	6		0.99	1.70676		
1.85	84.8	12.4	2.8		<1	6		0.49	0.84476		
3.69	74	21.2	4.8		<1	25		0.65	1.1206		
3.93	52.4	30.8	16.8		<1	7		0.61	1.05164		
1.04	91.2	6	2.8		<1	10		0.45	0.7758		
3.93	86.4	11.6	2		<1	4		0.78	1.34472		
2.33	64.4	34	1.6		<1	1		0.59	1.01716		
1.6	82.4	13.6	4		<1	3		0.55	0.9482		
1.28	85.6	12.8	1.6		<1	2		0.52	0.89648		

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
CR15-1-1	7.9	0.4	Low	4441	217	12.8	117	7.62	379	67.4	8.7	<0.01	0.14	1.15
CR15-1-2	8.0	0.2	Low	3751	140	0.38	83.3	7.45	226	53.1	3.5	0.04	0.06	0.75
CR15-1-3	7.8	0.4	Low	4606	181	1.55	94.3	7.40	317	67.1	5.3	0.01	0.14	0.99
CR15-2-1	7.8	0.3	Low	2199	107	4.73	45.5	8.57	238	54.3	2.7	0.04	0.05	0.47
CR15-2-2	7.9	0.1	Low	1882	94.8	16.6	44.2	6.26	243	50.1	9.6	0.14	0.10	2.25
CR15-2-3	8.1	0.1	Low	1616	124	0.38	38.8	6.59	286	53.4	4.1	<0.01	0.09	0.78
CR15-3-1	8.2	0.1	Low	1544	102	2.11	37.6	22.8	263	47.9	3.2	0.06	0.07	0.62
CR15-3-2	8.1	0.1	Low	1488	82.8	3.87	33.6	4.93	241	44.0	4.7	0.05	0.12	1.39
CR15-3-3	7.6	0.1	Low	2264	132	3.26	48.5	14.1	338	55.4	4.1	0.06	2.25	0.70
CR15-4-1	7.4	0.2	Low	2241	159	2.99	48.3	5.00	405	67.4	4.8	0.02	0.20	0.98
CR15-4-2	7.5	0.2	Low	1950	143	2.30	46.3	3.12	337	60.1	4.0	0.06	0.17	0.60
CR15-4-3	7.5	0.1	Low	1517	116	3.01	43.8	6.76	294	50.8	4.4	0.09	0.15	0.86
CR15-5-1	7.6	0.1	Low	2196	169	3.02	48.4	4.78	421	70.9	4.9	<0.01	0.16	0.95
CR15-5-2	7.6	0.1	Low	2191	166	4.77	45.9	6.47	417	71.9	6.1	<0.01	0.19	1.46
CR15-5-3	7.4	0.3	Low	1705	101	1.78	39.7	13.9	236	48.0	3.3	0.03	0.09	0.71
Ave	7.8	0.2		2372.7	135.6	4.2	54.4	8.4	309.5	57.4	4.9		0.3	1.0
CR16-1-1	7.4	0.3	Low	4363	183	3.55	87.5	5.20	263	59.4	2.8	0.01	0.11	1.37
CR16-1-2	7.6	0.3	Low	4887	249	3.77	92.7	4.33	343	75.2	3.2	<0.01	0.15	0.84
CR16-1-3	7.5	0.4	Low	4611	237	1.88	93.8	9.47	360	70.4	3.4	<0.01	0.19	0.82
CR16-2-1	7.4	0.5	Low	2593	206	2.62	71.0	5.41	329	65.4	3.7	<0.01	0.15	0.90
CR16-2-2	7.4	0.4	Low	2769	201	2.81	69.3	7.08	361	65.7	4.1	<0.01	0.15	0.86
CR16-2-3	7.1	0.4	Low	2875	228	3.22	84.0	5.51	351	74.1	3.6	<0.01	0.13	0.57
CR16-3-1	7.1	0.3	Low	1854	117	1.55	47.0	3.84	243	52.1	3.0	0.02	0.10	0.81
CR16-3-2	7.3	0.2	Low	4904	208	2.08	57.6	10.0	400	75.2	3.4	<0.01	0.34	0.76
CR16-3-3	7.2	0.3	Low	1534	108	0.67	46.9	2.71	219	49.4	2.5	0.02	0.11	0.73
CR16-4-1	7.3	0.2	Low	2231	149	1.17	64.8	3.84	275	58.8	3.3	0.03	0.10	0.55
CR16-4-2	7.2	0.5	Low	2809	159	0.85	73.7	4.03	260	55.4	2.8	0.04	0.10	0.26
CR16-4-3	7.1	0.4	Low	2316	172	1.98	60.0	12.33	311	62.2	3.7	0.02	0.12	1.19
CR16-5-1	7.4	0.2	Low	2074	180	2.69	63.7	9.63	337	66.5	4.7	0.00	0.13	1.19
CR16-5-2	7.1	0.5	Low	1959	147	4.68	77.4	4.08	239	56.1	3.3	0.03	0.11	0.85
CR16-5-3	7.1	0.4	Low	4214	313	4.21	122	11.5	486	115	6.7	<0.01	0.22	1.45
Ave	7.3	0.4		3066.2	190.4	2.5	74.1	6.6	318.4	66.7	3.6		0.1	0.9
CR17-1-1	7.6	0.4	Low	7851	242	1.39	42.2	8.37	365	120	4.2	<0.01	0.35	3.85
CR17-1-2	7.7	0.2	Low	5587	218	5.12	92.6	6.23	449	111	4.0	<0.01	1.50	6.95
CR17-1-3	7.5	0.3	Low	2122	107	4.91	40.4	3.78	279	40.3	1.9	<0.01	0.76	4.58

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH4-N (mg/kg)	NO3-N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
CR15-1-1	5.7	70	24	6	Sandy Loam	1.7	36.9	0.078	1.122	1.9	7.3	CR 15
CR15-1-2	6.3	72	24	4	Sandy Loam	6.0	8.4	0.063	0.983	1.7	7.2	CR 15
CR15-1-3	4.9	72	24	4	Sandy Loam	1.6	24.8	0.037	1.173	2.0	7.5	CR 15
CR15-2-1	5.5	78	22	0	Loamy Sand	5.3	14.3	0.062	0.945	1.6	7.5	CR 15
CR15-2-2	4.3	78	18	4	Loamy Sand	3.4	2.4	0.037	0.613	1.1	7.5	CR 15
CR15-2-3	5.4	66	28	6	Sandy Loam	5.4	2.5	0.060	0.730	1.3	7.5	CR 15
CR15-3-1	4.4	72	22	6	Sandy Loam	4.2	2.2	0.026	0.459	0.8	7.5	CR 15
CR15-3-2	5.2	74	22	4	Loamy Sand/Sandy Loam	3.2	2.0	0.041	0.746	1.3	7.5	CR 15
CR15-3-3	4.1	76	20	4	Loamy Sand	2.2	1.9	0.027	0.437	0.8	7.5	CR 15
CR15-4-1	5.1	68	26	6	Sandy Loam	5.3	6.9	0.034	0.590	1.0	7.5	CR 15
CR15-4-2	4.1	72	24	4	Sandy Loam	4.2	13.6	0.018	0.439	0.8	7.5	CR 15
CR15-4-3	4.9	70	24	6	Sandy Loam	2.4	2.4	0.044	0.586	1.0	7.5	CR 15
CR15-5-1	8.6	72	24	4	Sandy Loam	3.3	2.4	0.051	0.767	1.3	7.5	CR 15
CR15-5-2	7.4	72	22	6	Sandy Loam	2.0	2.5	0.048	0.633	1.1	7.4	CR 15
CR15-5-3	9.3	72	24	4	Sandy Loam	4.1	22.3	0.046	0.762	1.3	7.3	CR 15
Ave	5.7	72.3	23.2	4.5		3.6	9.7	0.0	0.7	1.3	7.4	
CR16-1-1	9.1	64	30	6	Sandy Loam	1.6	37.2	0.055	0.846	1.5	7.5	CR 16
CR16-1-2	14.2	64	22	14	Sandy Loam	1.5	28.0	0.081	1.204	2.1	7.2	CR 16
CR16-1-3	15.3	62	32	6	Sandy Loam	1.2	31.0	0.097	1.282	2.2	7.5	CR 16
CR16-2-1	4.1	64	30	6	Sandy Loam	2.0	48.5	0.036	0.400	0.7	7.4	CR 16
CR16-2-2	16.3	66	30	4	Sandy Loam	1.3	31.2	0.112	1.592	2.7	7.5	CR 16
CR16-2-3	14.1	66	30	4	Sandy Loam	1.8	51.9	0.078	1.121	1.9	7.5	CR 16
CR16-3-1	7.3	76	18	6	Loamy Sand/Sandy Loam	4.2	2.6	0.056	0.883	1.5	7.5	CR 16
CR16-3-2	9.5	70	24	6	Sandy Loam	5.1	1.6	0.088	1.241	2.1	7.5	CR 16
CR16-3-3	9.2	72	22	6	Sandy Loam	6.5	6.4	0.063	0.758	1.3	7.5	CR 16
CR16-4-1	11.4	64	30	6	Sandy Loam	7.3	3.3	0.074	1.139	2.0	7.5	CR 16
CR16-4-2	11.1	68	28	4	Sandy Loam	1.8	45.7	0.061	1.055	1.8	7.5	CR 16
CR16-4-3	10.5	68	26	6	Sandy Loam	1.9	34.6	0.063	0.968	1.7	7.5	CR 16
CR16-5-1	13.5	64	30	6	Sandy Loam	6.6	3.6	0.091	1.464	2.5	7.5	CR 16
CR16-5-2	12.2	62	32	6	Sandy Loam	6.6	32.5	0.075	1.307	2.3	7.5	CR 16
CR16-5-3	10.9	64	30	6	Sandy Loam	5.8	28.8	0.049	0.806	1.4	7.5	CR 16
Ave	11.2	66.3	27.6	6.1		3.7	25.8	0.1	1.1	1.8	7.5	
CR17-1-1	10.1	66	30	4	Sandy Loam	1.5	20.3	0.045	0.908	1.6	7.5	CR 17
CR17-1-2	11.1	64	30	6	Sandy Loam	5.9	3.3	0.049	0.828	1.4	7.5	CR 17
CR17-1-3	10.4	64	30	6	Sandy Loam	2.2	14.6	0.050	0.831	1.4	7.5	CR 17

Sample ID #	pH 1:1 (mmhos/ cm)	EC 1:1 (mmhos/ cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
CR 17-2-1	7.4	0.4	Low	3399	248	6.33	53.5	11.2	717	105	4.5	<0.01	1.82	9.79
CR 17-2-2	7.6	0.2	Low	2802	111	6.83	48.8	7.48	341	74.6	3.5	<0.01	0.95	6.32
CR 17-2-3	7.5	0.4	Low	3827	131	6.40	40.6	8.30	424	95.5	3.8	<0.01	1.12	8.21
CR 17-3-1	7.4	0.3	Low	2297	94.3	4.76	15.4	8.86	396	64.8	3.8	<0.01	1.00	6.32
CR 17-3-2	7.5	0.3	Low	1382	69.5	4.98	16.9	7.91	295	46.3	4.1	<0.01	0.69	7.26
CR 17-3-3	7.5	0.2	Low	2504	120	6.68	19.5	12.7	498	78.8	3.9	<0.01	1.95	9.95
CR 17-4-1	7.5	0.2	Low	2670	158	7.39	28.1	8.63	527	94.5	4.6	<0.01	1.36	7.58
CR 17-4-2	7.4	0.3	Low	2235	95.6	4.76	30.1	8.84	320	65.1	5.1	<0.01	0.99	9.16
CR 17-4-3	7.5	0.3	Low	2226	100	5.62	24.3	7.87	371	71.4	4.4	<0.01	1.17	8.21
CR 17-5-1	7.5	0.2	Low	2087	115	6.97	26.7	6.33	361	65.0	4.0	<0.01	0.87	7.11
CR 17-5-2	7.4	0.2	Low	2118	152	7.89	37.8	11.0	445	75.5	6.7	<0.01	0.97	6.95
CR 17-5-3	7.4	0.2	Low	2239	150	8.46	29.7	9.51	475	78.7	7.6	<0.01	1.21	8.84
Ave	7.5	0.3		3023.1	140.7	5.9	36.4	8.5	417.4	79.1	4.4		1.1	7.4
CR2-1-1	7.4	0.3	Low	3483	151	9.88	48.3	7.21	342	77.2	4.0	<0.01	0.82	4.74
CR2-1-2	7.6	0.2	Low	3317	247	7.93	59.7	5.05	549	86.9	3.7	<0.01	0.93	4.19
CR2-1-3	7.3	0.3	Low	3241	191	9.87	69.7	4.82	383	78.5	3.8	<0.01	0.80	5.02
CR2-2-1	7.6	0.2	Low	2904	134	12.5	62.8	5.25	283	70.9	3.7	<0.01	0.72	6.14
CR2-2-2	7.3	0.2	Low	3235	229	12.4	56.7	5.76	490	83.2	3.9	<0.01	0.88	7.40
CR2-2-3	7.4	0.2	Low	2747	146	11.5	53.6	5.59	341	71.4	3.6	<0.01	0.75	6.14
CR2-3-1	7.2	0.2	Low	3258	147	9.87	59.9	7.11	315	74.7	4.2	<0.01	0.80	5.16
CR2-3-2	7.4	0.2	Low	3019	152	10.6	47.2	8.25	342	69.9	4.3	<0.01	0.80	6.14
CR2-3-3	7.2	0.3	Low	3190	233	12.1	54.3	5.76	493	84.2	3.5	<0.01	0.92	7.26
CR2-4-1	7.3	0.3	Low	2939	155	10.1	44.3	4.50	332	70.7	3.1	<0.01	0.73	5.72
CR2-4-2	7.2	0.3	Low	3422	168	9.20	60.5	5.17	327	78.2	3.5	<0.01	0.85	5.16
CR2-4-3	7.6	0.2	Low	3530	274	11.1	47.6	6.65	605	94.8	3.9	<0.01	1.04	6.42
CR2-5-1	7.4	0.2	Low	3159	223	9.80	45.6	5.45	441	76.7	3.0	<0.01	0.89	5.72
CR2-5-2	7.3	0.3	Low	3759	271	10.1	66.9	5.82	516	88.3	3.3	<0.01	0.93	5.86
CR2-5-3	7.3	0.3	Low	3490	244	11.1	52.0	5.74	517	87.4	3.6	<0.01	0.92	6.56
Ave	7.4	0.2		3246.2	197.6	10.5	55.3	5.9	418.3	79.5	3.7		0.9	5.8
CR7-1-1	7.6	0.2	Low	3988	185	7.07	39.4	2.63	395	129	3.3	<0.01	1.06	5.44
CR7-1-2	7.8	0.1	Low	3615	160	7.80	26.3	2.45	366	105	3.3	<0.01	0.95	6.56
CR7-1-3	7.7	0.1	Low	4026	145	7.53	30.9	3.16	330	105	3.3	<0.01	0.99	6.56
CR7-2-1	7.6	0.1	Low	1341	76.5	6.13	8.1	2.53	257	54.4	3.2	<0.01	0.61	4.33
CR7-2-2	7.7	0.1	Low	1216	69.1	6.80	7.3	2.72	245	54.3	3.1	<0.01	0.61	6.42
CR7-2-3	7.7	0.1	Low	1288	81.4	5.00	9.8	2.45	268	55.1	2.8	<0.01	0.64	4.19

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH4-N (mg/kg)	NO3-N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
CR 17-2-1	5.6	62	32	6	Sandy Loam	2.4	16.8	0.029	0.526	0.9	7.5	CR 17
CR 17-2-2	12.2	64	30	6	Sandy Loam	5.0	2.7	0.049	0.884	1.5	7.5	CR 17
CR 17-2-3	11.4	70	26	4	Sandy Loam	1.9	1.6	0.056	0.761	1.3	7.5	CR 17
CR 17-3-1	3.4	80	16	4	Loamy Sand	1.2	0.8	0.017	0.349	0.6	7.5	CR 17
CR 17-3-2	10.5	82	14	4	Loamy Sand	1.3	0.8	0.020	0.899	1.5	7.5	CR 17
CR 17-3-3	3.5	80	16	4	Loamy Sand	2.8	0.9	0.017	0.325	0.6	7.5	CR 17
CR 17-4-1	4.9	72	22	6	Sandy Loam	4.6	2.5	0.044	0.537	0.9	7.5	CR 17
CR 17-4-2	8.5	74	22	4	Loamy Sand/Sandy Loam	1.6	34.2	0.045	0.711	1.2	7.5	CR 17
CR 17-4-3	6.2	74	22	4	Loamy Sand/Sandy Loam	1.7	0.7	0.041	0.603	1.0	7.5	CR 17
CR 17-5-1	6.4	72	24	4	Sandy Loam	5.5	3.8	0.058	0.687	1.2	7.5	CR 17
CR 17-5-2	10.3	76	20	4	Loamy Sand	2.4	23.3	0.080	0.873	1.5	7.5	CR 17
CR 17-5-3	7.4	76	20	4	Loamy sand	2.0	18.8	0.047	0.682	1.2	7.5	CR 17
Ave	8.1	71.7	23.6	4.7		2.8	9.7	0.0	0.7	1.2	7.5	
CR2-1-1	17.4	46	48	6	Sandy Loam	4.9	5.6	0.114	1.657	2.9	7.5	CR 2
CR2-1-2	16.3	44	50	6	Silt Loam/Sandy Loam	5.1	7.1	0.091	1.279	2.2	7.5	CR 2
CR2-1-3	21.0	44	50	6	Silt Loam/Sandy Loam	2.1	45.8	0.119	1.936	3.3	7.5	CR 2
CR2-2-1	23.4	46	46	8	Loam	8.8	10.5	0.148	2.260	3.9	7.5	CR 2
CR2-2-2	25.4	48	44	8	Loam	1.7	34.1	0.320	3.917	6.8	7.5	CR 2
CR2-2-3	23.5	48	46	6	Sandy Loam	5.9	17.2	0.166	2.430	4.2	7.5	CR 2
CR2-3-1	26.2	46	46	8	Loam	3.2	5.8	0.216	3.525	6.1	7.5	CR 2
CR2-3-2	22.4	44	48	8	Loam	1.5	20.2	0.152	2.628	4.5	7.5	CR 2
CR2-3-3	21.4	42	52	6	Silt Loam	2.6	36.1	0.131	2.031	3.5	7.5	CR 2
CR2-4-1	18.5	46	48	6	Sandy Loam	4.5	3.3	0.115	1.818	3.1	7.5	CR 2
CR2-4-2	22.4	48	48	4	Sandy Loam	3.9	5.0	0.152	2.165	3.7	7.5	CR 2
CR2-4-3	13.5	44	52	4	Silt Loam	7.3	2.5	0.094	1.455	2.5	7.5	CR 2
CR2-5-1	19.5	48	46	6	Sandy Loam	1.4	27.7	0.157	1.948	3.4	7.5	CR 2
CR2-5-2	26.2	48	46	6	Sandy Loam	2.2	29.7	0.138	1.768	3.0	7.5	CR 2
CR2-5-3	4.2	44	48	8	Loam	3.7	8.1	0.160	2.458	4.2	7.5	CR 2
Ave	20.1	45.7	47.9	6.4		3.9	17.2	0.2	2.2	3.8	7.5	
CR7-1-1	4.0	70	22	8	Sandy Loam	1.1	1.3	0.028	0.580	1.0	7.5	CR 7
CR7-1-2	3.2	76	16	8	Sandy Loam	1.3	1.6	0.019	0.425	0.7	7.5	CR 7
CR7-1-3	3.1	76	16	8	Sandy Loam	0.8	1.1	0.007	0.373	0.6	7.5	CR 7
CR7-2-1	4.2	90	4	6	Sand	<0.1	2.0	0.033	0.429	0.7	7.5	CR 7
CR7-2-2	4.5	88	8	4	Sand	0.4	1.0	0.023	0.496	0.9	7.5	CR 7
CR7-2-3	3.9	92	4	4	Sand	0.7	1.1	0.026	0.348	0.6	7.5	CR 7

Sample ID #	pH 1:1 (mmhos/cm)	EC 1:1 (mmhos/cm)	Lime Est	Ca* (ppm)	Mg* (ppm)	P* (ppm)	K* (ppm)	Zn* (ppm)	Fe* (ppm)	Mn* (ppm)	Cu* (ppm)	Cd* (ppm)	Cr* (ppm)	Pb* (ppm)
CR7-3-1	7.5	0.2	Low	846	84.9	7.13	12.6	3.10	277	51.9	3.4	<0.01	0.47	5.58
CR7-3-2	7.5	0.1	Low	138	154	6.93	18.8	3.95	453	86.2	3.5	<0.01	0.64	5.86
CR7-3-3	7.5	0.1	Low	815	94.0	9.53	13.3	3.28	306	53.8	3.7	<0.01	0.41	7.54
CR7-4-1	7.4	0.1	Low	1387	176	9.07	40.9	9.89	453	89.3	3.2	<0.01	0.71	6.14
CR7-4-2	7.4	0.1	Low	1191	157	7.57	49.5	16.0	387	79.1	2.9	<0.01	0.71	4.20
CR7-4-3	7.4	0.1	Low	1216	152	7.04	37.9	8.44	362	72.0	3.3	<0.01	0.70	4.05
CR7-5-1	7.2	0.2	Low	1718	201	8.87	47.5	18.1	356	85.6	3.0	<0.01	0.72	4.50
CR7-5-2	7.5	0.1	Low	1786	213	10.1	51.9	9.25	367	86.4	2.5	<0.01	0.87	5.10
CR7-5-3	7.5	0.1	Low	1660	192	11.4	54.8	13.7	362	85.4	2.6	<0.01	0.70	6.15
Ave	7.5	0.1		1748.7	142.8	7.9	29.9	6.8	345.5	79.5	3.1		0.7	5.5
CR9-1-1	8.0	0.2	Low	4157	203	10.8	102	12.8	502	105	3.9	<0.01	1.11	6.75
CR9-1-2	7.7	0.3	Low	3671	194	11.3	53.2	9.21	521	108	7.3	<0.01	1.18	7.65
CR9-1-3	7.7	0.1	Low	4499	262	10.6	48.3	36.2	670	262	4.8	<0.01	1.37	8.10
CR9-2-1	7.8	0.2	Low	2778	220	8.48	31.0	9.16	721	220	7.1	<0.01	1.11	7.95
CR9-2-2	7.8	0.3	Low	2641	155	10.2	37.1	8.59	509	155	5.1	<0.01	0.89	8.70
CR9-2-3	7.8	0.3	Low	3088	166	8.94	31.2	14.6	537	166	4.6	<0.01	1.01	7.65
CR9-3-1	7.6	0.2	Low	2014	157	9.13	27.8	11.4	515	157	13.8	<0.01	0.84	8.10
CR9-3-2	7.8	0.1	Low	1972	158	10.8	31.9	12.1	458	158	4.3	<0.01	0.81	7.80
CR9-3-3	7.5	0.3	Low	2138	198	9.39	36.8	16.2	662	198	5.4	<0.01	0.96	7.95
CR9-4-1	7.6	0.2	Low	1963	179	9.39	33.4	12.6	548	179	7.1	<0.01	0.89	8.10
CR9-4-2	7.6	0.2	Low	1951	179	11.7	35.8	17.2	540	179	6.8	<0.01	0.90	9.60
CR9-4-3	7.8	0.2	Low	1918	217	10.4	33.6	26.0	712	217	10.9	<0.01	1.05	9.00
CR9-5-1	7.7	0.3	Low	1970	167	9.59	34.9	14.2	540	167	6.9	<0.01	0.89	8.25
CR9-5-2	7.5	0.3	Low	1948	180	10.5	29.8	12.9	563	180	6.1	<0.01	0.85	9.30
CR9-5-3	7.4	0.3	Low	1874	178	8.61	33.0	14.4	519	178	7.0	<0.01	0.85	7.80
Ave	7.7	0.2		2572.1	187.4	10.0	40.0	15.2	567.9	175.2	6.7		1.0	8.2

Sample ID #	CEC (meq /100g)	% Sand	% Silt	% Clay	Texture	NH4-N (mg/kg)	NO3-N (mg/kg)	Total % N	Total % C	% calc OM	Buffer pH	Ecotype
CR7-3-1	4.1	82	14	4	Loamy Sand	2.0	1.9	0.022	0.451	0.8	7.5	CR7
CR7-3-2	5.9	80	16	4	Loamy Sand	1.2	1.8	0.044	0.641	1.1	7.5	CR7
CR7-3-3	5.4	80	16	4	Loamy Sand	1.1	1.2	0.043	0.594	1.0	7.5	CR7
CR7-4-1	22.5	62	34	4	Sandy Loam	2.6	2.0	0.144	2.005	3.5	7.5	CR7
CR7-4-2	15.4	64	30	6	Sandy Loam	2.3	2.5	0.104	1.483	2.6	7.5	CR7
CR7-4-3	12.5	56	36	8	Sandy Loam	2.9	2.2	0.089	1.176	2.0	7.5	CR7
CR7-5-1	26.4	54	38	8	Sandy Loam	1.4	31.1	0.155	2.319	4.0	7.5	CR7
CR7-5-2	27.5	58	34	8	Sandy Loam	8.2	4.2	0.208	2.829	4.9	7.5	CR7
CR7-5-3	26.3	54	38	8	Sandy Loam	4.8	3.0	0.209	2.763	4.8	7.5	CR7
Ave	11.3	72.1	21.7	6.1		2.1	3.9	0.1	1.1	1.9	7.5	
CR9-1-1	12.4	56	36	8	Sandy Loam	5.4	3.0	0.072	1.068	1.8	7.5	CR9
CR9-1-2	11.5	62	30	8	Sandy Loam	1.1	35.3	0.070	0.961	1.7	7.5	CR9
CR9-1-3	14.0	62	30	8	Sandy Loam	4.5	2.6	0.086	1.207	2.1	7.5	CR9
CR9-2-1	6.4	66	24	10	Sandy Loam	1.1	27.3	0.047	0.640	1.1	7.5	CR9
CR9-2-2	4.2	70	22	8	Sandy Loam	1.5	28.7	0.034	0.576	1.0	7.5	CR9
CR9-2-3	7.2	58	34	8	Sandy Loam	1.0	30.4	0.044	0.623	1.1	7.5	CR9
CR9-3-1	5.3	54	38	8	Sandy Loam	1.5	22.3	0.043	0.581	1.0	7.5	CR9
CR9-3-2	5.4	60	32	8	Sandy Loam	2.3	3.9	0.059	0.827	1.4	7.5	CR9
CR9-3-3	7.3	64	28	8	Sandy Loam	1.1	36.2	0.044	0.568	1.0	7.5	CR9
CR9-4-1	7.7	58	34	8	Sandy Loam	1.3	22.2	0.048	0.611	1.1	7.5	CR9
CR9-4-2	9.4	62	30	8	Sandy Loam	1.3	27.1	0.058	0.868	1.5	7.5	CR9
CR9-4-3	6.8	60	28	12	Sandy Loam	3.6	20.3	0.060	0.811	1.4	7.5	CR9
CR9-5-1	7.2	64	28	8	Sandy Loam	1.7	32.0	0.076	0.683	1.2	7.5	CR9
CR9-5-2	8.5	62	30	8	Sandy Loam	1.0	39.1	0.060	0.723	1.2	7.5	CR9
CR9-5-3	10.2	64	28	8	Sandy Loam	0.7	46.6	0.048	0.899	1.5	7.5	CR9
Ave	8.2	61.5	30.1	8.4		1.9	25.1	0.1	0.8	1.3	7.5	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.878704464
R Square	0.772121534
Adjusted R Square	0.770670079
Standard Error	6.416563842
Observations	159

ANOVA

	df	SS	MS	F	Significance F
Regression	1	21902.1662	21902.1662	531.9637403	2.74386E-52
Residual	157	6464.049772	41.17229154		
Total	158	28366.21597			

PARAMETER ESTIMATES

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	4.98805884	0.688799478	7.241670465	1.86558E-11	3.627548604	6.348569075
X Variable OM	2.422021342	0.105011521	23.06433915	2.74386E-52	2.214603576	2.629439109

RESIDUAL OUTPUT

Observation	Plot	Observed Y	Predicted Y	Residuals	Standard Residuals
1	108	2.2	6.704	7.596	1.188
2	2501	2.4	16.103	2.440	0.382
3	CR7-1-3	3.1	6.546	-3.538	-0.553
4	CR7-1-2	3.2	6.763	-2.468	-0.386
5	CR 17-3-1	3.4	6.445	-2.268	-0.355
6	CR 17-3-3	3.5	6.345	-3.439	-0.538
7	CR7-2-3	3.9	6.441	-3.611	-0.565
8	CR7-1 -1	4.0	7.410	-2.090	-0.327
9	CR15-3-3	4.1	6.813	-3.270	-0.511
10	CR 15-4-2	4.1	6.821	-4.504	-0.704
11	CR 16-2-1	4.1	6.658	-6.675	-1.044
12	CR7-3-1	4.1	6.871	-4.270	-0.668
13	CR2-5-3	4.2	15.252	-3.300	-0.516
14	CR7-2-1	4.2	6.779	-3.904	-0.610
15	CR9-2-2	4.2	7.393	-3.861	-0.604
16	CR1 5-2-2	4.3	7.548	-4.647	-0.727
17	CR 15-3-1	4.4	6.905	-3.694	-0.577
18	CR7-2-2	4.5	7.059	-0.807	-0.126
19	E07	4.9	5.243	3.552	0.555
20	CR15-1-3	4.9	9.886	5.757	0.900
21	CR 15-4-3	4.9	7.435	2.047	0.320
22	CR 17-4-1	4.9	7.230	9.203	1.439
23	CR 15-4-1	5.1	7.452	4.692	0.733
24	CR15-3-2	5.2	8.103	9.515	1.488
25	CR9-3-1	5.3	7.414	-0.369	-0.058
26	CR 15-2-3	5.4	8.036	1.944	0.304
27	CR7-3-3	5.4	7.468	2.817	0.440
28	CR9-3-2	5.4	8.441	2.538	0.397

Ecotype	Scrub W	Scrub J	Broadleaf	Mixed
Code	A	B	C	D
Comparison	A-B	--		--
	A-C	B-C	--	--
	A-D	B-D	C-D	--

Ecotype	Scrub W	Scrub J	Broadleaf	Mixed
% Organic Matter	4.98	2.01	8.68	5.58
	3.28	2.63	7.66	19.10
	3.34	2.73	9.93	11.36
	3.38	1.95	17.26	24.95
	1.76	4.06	14.81	6.63
	3.73	18.86	15.19	5.48
	2.73	8.83	11.18	12.01
	2.10	17.93	10.21	16.52
	0.71	13.13	7.44	10.64
	4.78	13.89	7.51	7.89
	2.10	15.46	14.67	11.54
	3.10	23.26	10.05	5.97

Descriptive Statistics	Scrub W	Scrub J	Broadleaf	Mixed
Mean	2.998036	10.394	11.21678	11.47164
Standard Error	0.35349	2.206341	0.985813	1.74832
Median	3.191986	10.97929	10.13022	10.99912
Mode	2.098108	#N/A	#N/A	#N/A
Standard Deviation	1.224524	7.642989	3.414958	6.056357
Sample Variance	1.499458	58.41528	11.66194	36.67946
Kurtosis	-0.02208	-1.47804	-1.14837	0.784335
Skewness	-0.08112	0.241315	0.549006	1.116313
Range	4.27552	21.30692	9.816456	19.46913
Minimum	0.708564	1.949844	7.440784	5.477148
Maximum	4.984084	23.25676	17.25724	24.94628
Sum	35.97643	124.728	134.6013	137.6597
Count	12	12	12	12
Conf Level(95.0%)	0.778026	4.856126	2.169762	3.848027

Summary of t-Tests	Scrub W	Scrub J	Broadleaf	Mixed
No evidence to reject Ho:				
Means are equal				

B to C % OM

Scrub J	Broadleaf
2.01	8.68
2.63	7.66
2.73	9.93
1.95	17.26
4.06	14.81
18.86	15.19
8.83	11.18
17.93	10.21
13.13	7.44
13.89	7.51
15.46	14.67
23.26	10.05

t-Test: Two-Sample Assuming Unequal Variances

	Scrub J	Broadleaf
Mean	10.394	11.21678
Variance	58.41528	11.66194
Observations	12	12
Hypothesized Mean Difference	0	
df	15	
t Stat	-0.34048	
P(T<=t) one-tail	0.36911	
t Critical one-tail	1.753051	
P(T<=t) two-tail	0.73822	
t Critical two-tail	2.131451	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: No evidence to reject Ho

A to B % OM

Scrub W	Scrub J
4.98	2.01
3.28	2.63
3.34	2.73
3.38	1.95
1.76	4.06
3.73	18.86
2.73	8.83
2.10	17.93
0.71	13.13
4.78	13.89
2.10	15.46
3.10	23.26

t-Test: Two-Sample Assuming Unequal Variances

	Scrub W	Scrub J
Mean	2.998036	10.394
Variance	1.499458	58.41528
Observations	12	12
Hypothesized Mean Difference	0	
df	12	
t Stat	-3.30993	
P(T<=t) one-tail	0.003113	
t Critical one-tail	1.782287	
P(T<=t) two-tail	0.006225	
t Critical two-tail	2.178813	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: Reject Ho, means are not equal.

B to D % OM

Scrub J	Mixed
2.01	5.58
2.63	19.10
2.73	11.36
1.95	24.95
4.06	6.63
18.86	5.48
8.83	12.01
17.93	16.52
13.13	10.64
13.89	7.89
15.46	11.54
23.26	5.97

t-Test: Two-Sample Assuming Unequal Variances

	Scrub J	Mixed
Mean	10.394	11.47164
Variance	58.41528	36.67946
Observations	12	12
Hypothesized Mean Difference	0	
df	21	
t Stat	-0.38281	
P(T<=t) one-tail	0.352853	
t Critical one-tail	1.720744	
P(T<=t) two-tail	0.705705	
t Critical two-tail	2.079614	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: No evidence to reject Ho

A to C % OM

Scrub W	Broadleaf
4.98	8.68
3.28	7.66
3.34	9.93
3.38	17.26
1.76	14.81
3.73	15.19
2.73	11.18
2.10	10.21
0.71	7.44
4.78	7.51
2.10	14.67
3.10	10.05

t-Test: Two-Sample Assuming Unequal Variances

	Scrub W	Broadleaf
Mean	2.998036	11.21678
Variance	1.499458	11.66194
Observations	12	12
Hypothesized Mean Difference	0	
df	14	
t Stat	-7.84774	
P(T<=t) one-tail	8.56E-07	
t Critical one-tail	1.761309	
P(T<=t) two-tail	1.71E-06	
t Critical two-tail	2.144789	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: Reject Ho, means are not equal.

C to D % OM

Broadleaf	Mixed
8.68	5.58
7.66	19.10
9.93	11.36
17.26	24.95
14.81	6.63
15.19	5.48
11.18	12.01
10.21	16.52
7.44	10.64
7.51	7.89
14.67	11.54
10.05	5.97

t-Test: Two-Sample Assuming Unequal Variances

	Broadleaf	Mixed
Mean	11.21678	11.47164
Variance	11.66194	36.67946
Observations	12	12
Hypothesized Mean Difference	0	
df	17	
t Stat	-0.12698	
P(T<=t) one-tail	0.450222	
t Critical one-tail	1.739606	
P(T<=t) two-tail	0.900445	
t Critical two-tail	2.109819	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: No evidence to reject Ho

A to D % OM

Scrub W	Mixed
4.98	5.58
3.28	19.10
3.34	11.36
3.38	24.95
1.76	6.63
3.73	5.48
2.73	12.01
2.10	16.52
0.71	10.64
4.78	7.89
2.10	11.54
3.10	5.97

t-Test: Two-Sample Assuming Unequal Variances

	Scrub W	Mixed
Mean	2.998036	11.47164
Variance	1.499458	36.67946
Observations	12	12
Hypothesized Mean Difference	0	
df	12	
t Stat	-4.75058	
P(T<=t) one-tail	0.000236	
t Critical one-tail	1.782287	
P(T<=t) two-tail	0.000472	
t Critical two-tail	2.178813	

Ho: Means are equal (difference = 0)

Ha: Means are not equal (difference not equal to 0)

alpha = .05

Conclusion: Reject Ho, means are not equal.

	CEC	% OM		CEC	% OM
Plot	Plot	Plot	Crater	Crater	Crater
E05	9.8	3.4	17	8.13	1.20
E07	4.9	0.1	16	11.25	1.85
G01	21.1	8.7	15	5.68	1.26
I01	15.4	5.0	9	8.23	1.34
I04	5.5	2.5	7	11.26	1.94
I06	8.2	2.3			
J03	47.9	4.4			
J06	8.2	1.4			
K03	17.6	4.2			
K04	8.6	2.3			
K05	8.8	1.6			
L04	8.6	1.6			

t-Test: Two-Sample Assuming Unequal Variances

	% OM	Plot	Crater
Mean		3.119865	1.517419
Variance		5.078074	0.122624
Observations		12	5
Hypothesized Mean Difference		0	
df		12	
t Stat		2.394921	
P(T<=t) one-tail		0.016915	
t Critical one-tail		1.782287	
P(T<=t) two-tail		0.033831	
t Critical two-tail		2.178813	

t-Test: Two-Sample Assuming Unequal Variances

	CEC	Plot	Crater
Mean		13.71667	8.909333
Variance		139.9015	5.621724
Observations		12	5
Hypothesized Mean Difference		0	
df		13	
t Stat		1.344594	
P(T<=t) one-tail		0.100874	
t Critical one-tail		1.770932	
P(T<=t) two-tail		0.201748	
t Critical two-tail		2.160368	

Plot	CEC	% OM	Crater	CEC	% OM
Plot	Plot	Plot	Crater	Crater	Crater
100	19.5	5.0	17	8.13	1.20
101	9.4	3.3	16	11.25	1.85
102	10.6	3.3	15	5.68	1.26
103	10.9	3.4	9	8.23	1.34
104	5.8	1.8	7	11.26	1.94
105	10.4	3.7			
106	9.5	2.7			
107	6.8	2.1			
108	2.2	0.7			
109	9.9	4.8			
110	5.8	2.1			
111	9.2	3.1			

t-Test: Two-Sample Assuming Unequal Variances

% OM	Plot	Crater
Mean	2.998036	1.517419
Variance	1.499458	0.122624
Observations	12	5
Hypothesized Mean Difference	0	
df	14	
t Stat	3.829585	
P(T<=t) one-tail	0.00092	
t Critical one-tail	1.761309	
P(T<=t) two-tail	0.00184	
t Critical two-tail	2.144789	


t-Test: Two-Sample Assuming Unequal Variances

CEC	Plot	Crater
Mean	9.166667	8.909333
Variance	17.35152	5.621724
Observations	12	5
Hypothesized Mean Difference	0	
df	13	
t Stat	0.160511	
P(T<=t) one-tail	0.437473	
t Critical one-tail	1.770932	
P(T<=t) two-tail	0.874946	
t Critical two-tail	2.160368	

Comparisons	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Ring 1		X	X	X	X
Ring 2			X	X	X
Ring 3				X	X
Ring 4					X
Ring 5					

Ring	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
% Organic Matter	1.00	0.74	0.78	3.46	4.00
	0.73	0.86	1.11	2.56	4.88
	0.64	0.60	1.02	2.03	4.76

Descriptive Statistics	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Mean	0.791891	0.731551	0.968888	2.680245	4.546188
Standard Error	0.107186	0.073766	0.0985	0.417173	0.276077
Median	0.7327	0.739596	1.024056	2.556692	4.763412
Mode	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0.185651	0.127766	0.170606	0.722564	0.478179
Sample Variance	0.034466	0.016324	0.029107	0.522099	0.228655
Kurtosis	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Skewness	1.288882	-0.282238	-1.302984	0.74697	-1.622374
Range	0.356868	0.255152	0.32756	1.429196	0.87924
Minimum	0.643052	0.599952	0.777524	2.027424	3.997956
Maximum	0.99992	0.855104	1.105084	3.45662	4.877196
Sum	2.375672	2.194652	2.906664	8.040736	13.63856
Count	3	3	3	3	3
Confidence Level(95.0%)	0.461183	0.317389	0.42381	1.794951	1.187864

Summary of tests	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
No evidence to reject Ho: Means are equal 					

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 2
Mean	0.791891	0.731551
Variance	0.034466	0.016324
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	0.46374	
P(T<=t) one-tail	0.333473	
t Critical one-tail	2.131846	
P(T<=t) two-tail	0.666946	
t Critical two-tail	2.776451	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 3
Mean	0.731551	0.968888
Variance	0.016324	0.029107
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-1.928644	
P(T<=t) one-tail	0.063006	
t Critical one-tail	2.131846	
P(T<=t) two-tail	0.126012	
t Critical two-tail	2.776451	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 3	Ring 4
Mean	0.968888	2.680245
Variance	0.029107	0.522099
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-3.992495	
P(T<=t) one-tail	0.028694	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.057388	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 4	Ring 5
Mean	2.680245	4.546188
Variance	0.522099	0.228655
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-3.730009	
P(T<=t) one-tail	0.016787	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.033575	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 3
Mean	0.791891	0.968888
Variance	0.034466	0.029107
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-1.215882	
P(T<=t) one-tail	0.145439	
t Critical one-tail	2.131846	
P(T<=t) two-tail	0.290877	
t Critical two-tail	2.776451	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 4
Mean	0.731551	2.680245
Variance	0.016324	0.522099
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-4.599837	
P(T<=t) one-tail	0.022078	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.044156	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 3	Ring 5
Mean	0.968888	4.546188
Variance	0.029107	0.228655
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-12.20412	
P(T<=t) one-tail	0.000592	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.001185	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 4
Mean	0.791891	2.680245
Variance	0.034466	0.522099
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-4.384156	
P(T<=t) one-tail	0.024145	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.048289	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 5
Mean	0.731551	4.546188
Variance	0.016324	0.228655
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-13.34901	
P(T<=t) one-tail	0.002782	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.005565	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 5
Mean	0.791891	4.546188
Variance	0.034466	0.228655
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-12.67684	
P(T<=t) one-tail	0.000529	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.001059	
t Critical two-tail	3.182449	


Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

Comparisons	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Ring 1		X	X	X	X
Ring 2			X	X	X
Ring 3				X	X
Ring 4					X
Ring 5					

Ring	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
% Organic Matter	1.57	0.91	0.60	0.93	1.18
	1.43	1.52	1.55	1.23	1.51
	1.43	1.31	0.56	1.04	1.18

Descriptive Statistics	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Mean	1.475169	1.247601	0.903951	1.063708	1.288403
Standard Error	0.045136	0.181051	0.323183	0.087432	0.108353
Median	1.432644	1.311964	0.601676	1.039572	1.184388
Mode	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0.078178	0.31359	0.55977	0.151437	0.187673
Sample Variance	0.006112	0.098338	0.313343	0.022933	0.035221
Kurtosis	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Skewness	1.723526	-0.884695	1.721411	0.698989	1.727941
Range	0.13792	0.617192	0.989576	0.299976	0.329284
Minimum	1.427472	0.906824	0.5603	0.925788	1.175768
Maximum	1.565392	1.524016	1.549876	1.225764	1.505052
Sum	4.425508	3.742804	2.711852	3.191124	3.865208
Count	3	3	3	3	3
Confidence Level(95.0%)	0.194205	0.779	1.390547	0.376192	0.466207

Summary of tests	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
No evidence to reject Ho: Means are equal 					

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 2
Mean	1.475169	1.247601
Variance	0.006112	0.098338
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	1.219599	
P(T<=t) one-tail	0.173461	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.346922	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 3
Mean	1.247601	0.903951
Variance	0.098338	0.313343
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	0.927678	
P(T<=t) one-tail	0.211	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.422001	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 3	Ring 4
Mean	0.903951	1.063708
Variance	0.313343	0.022933
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-0.47717	
P(T<=t) one-tail	0.340149	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.680298	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 4	Ring 5
Mean	1.063708	1.288403
Variance	0.022933	0.035221
Observations	3	3
Hypothesized Mean Difference	0	
df	4	
t Stat	-1.613843	
P(T<=t) one-tail	0.09093	
t Critical one-tail	2.131846	
P(T<=t) two-tail	0.18186	
t Critical two-tail	2.776451	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 3
Mean	1.475169	0.903951
Variance	0.006112	0.313343
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	1.750486	
P(T<=t) one-tail	0.111068	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.222137	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 4
Mean	1.247601	1.063708
Variance	0.098338	0.022933
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	0.914633	
P(T<=t) one-tail	0.213914	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.427828	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 3	Ring 5
Mean	0.903951	1.288403
Variance	0.313343	0.035221
Observations	3	3
Hypothesized Mean Difference	0	
df	2	
t Stat	-1.127876	
P(T<=t) one-tail	0.188242	
t Critical one-tail	2.919987	
P(T<=t) two-tail	0.376484	
t Critical two-tail	4.302656	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 4
Mean	1.475169	1.063708
Variance	0.006112	0.022933
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	4.181704	
P(T<=t) one-tail	0.012459	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.024918	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: Reject Ho, means are not equal.

t-Test: Two-Sample Assuming Unequal Variances

	Ring 2	Ring 5
Mean	1.247601	1.288403
Variance	0.098338	0.035221
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	-0.193374	
P(T<=t) one-tail	0.429509	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.859018	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho

t-Test: Two-Sample Assuming Unequal Variances

	Ring 1	Ring 5
Mean	1.475169	1.288403
Variance	0.006112	0.035221
Observations	3	3
Hypothesized Mean Difference	0	
df	3	
t Stat	1.59115	
P(T<=t) one-tail	0.104904	
t Critical one-tail	2.353363	
P(T<=t) two-tail	0.209808	
t Critical two-tail	3.182449	

Ho: Means are equal (difference = 0)
Ha: Means are not equal (difference not equal to 0)
alpha = .05

Conclusion: No evidence to reject Ho